# FARM CROPS

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BY MANY SPECIALISTS

UNDER THE EDITORSHIP OF

WILLIAM G. R. PATERSON

B.Sc., N.D.A.(Hons.)

Principal and Professor of Agriculture
The West of Scotland Agricultural College



VOLUME II

ROOT CROPS



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# THE EARLY POTATO CROP

By J. M. HANNAH

The two most essential conditions for the successful production of potatoes for the early market are suitable soil and climate. It is not necessary that the soil be specially fertile, but it must be dry and well drained. It must also be situated so as to escape as far as possible severe frost during the period of growth.

### The Early Potato Areas.

Certain districts have made a speciality of catering for the early market. Notable amongst these are the Island of Jersey, parts of Cornwall, Lancashire, and Cheshire, in England, and of Ayrshire, in Scotland. Other districts have in recent years contributed to the supply, but only to a limited extent and mainly for local consumption.

**Island of Jersey Practice.**—The production of potatoes in the Island of Jersey has been carried on for many years, and has assumed such proportions that it is difficult for an outsider to realize the magnitude of the industry. Situated as it is, far enough south to secure the advantages of brilliant sunshine and comparative freedom from spring frost, and yet near enough to be within a reasonable distance of the best English markets, the island can well hope to retain the monopoly it has so long enjoyed of supplying the demand in the earlier part of the season.

The mean temperature is 52·2° F. and the rainfall about 30 in. per annum. Land is under crop which in many countries would be lying waste, and some of it is so steep that it makes one wonder how the soil keeps in position. Earthen banks and hedges of shrubs and trees provide good shelter from wind storms.

About 7000 ac., or one-third of the entire island, is set apart for the growth of potatoes, and 50,000 tons are annually shipped to market. The rotation usually followed is three crops of potatoes in succession, followed by grain, hay, and then pasture for two or three seasons.

Seaweed is collected around the coast and applied to the land along with the dung made on the island. These dressings are skimmed in in the winter months, and the land is again ploughed in the spring to a depth of 9 or 10 in. After ploughing the land, labour is mostly done by hand, and many of those employed to cultivate and harvest the crop come from France.

The main portion of the crop is planted in February. The sets are planted very closely, the rows being 16 in. apart, and the sets 10 to 12 in. apart in the row.

Artificial manure containing $4\frac{1}{2}$ per cent nitrogen (N), 18 to 20 per cent phosphates, $[Ca_3(PO_4)_2]$, and 5 per cent pure potash ($K_2O$), is sown broadcast at the rate of $12\frac{1}{2}$ cwt. per acre and harrowed in before planting.

The crop is usually ready for marketing about the end of May, and the average yield is from 7 to 10 tons per acre, but many of these potatoes are lifted before reaching maturity. Growers lift the crop and cart the produce to the shipping port of St. Heliers, where it is sold to merchants, packed in small barrels or boxes, and sent to the different markets.

**Cornwall Practice.**—The practice in Cornwall does not differ greatly from that adopted in Jersey. The rainfall there is around 40 in., and the mean temperature about 51° F. Potatoes are grown in consecutive years on the same land, and the work is chiefly done by hand labour.

The land is ploughed in spring to a depth of 6 or 7 in., after an application of seaweed and farmyard manure at the rate of 40 to 50 tons per acre. Some growers apply the dung on the surface after the land has been ploughed.

About 16 cwt. of guano and dissolved bones are sown at the time of planting, and 4 cwt. nitrate of soda as a top dressing when the crop is growing.

May Queen and Sharpe's Express are the varieties grown, and 40 cwt. seed are required to plant an acre. The yield runs from 5 to 8 tons at the beginning of the season, and lifting usually begins about the end of May.

**Cheshire and Lancashire Practice.**—In Cheshire and Lancashire a considerable area of land is devoted to the growth of potatoes, and a portion of the crop is lifted in a green state and sent direct to market. The rainfall is about 32 in. per annum, and the mean temperature 48° F. The district has not the same immunity from frost as farther south or near to the coast line.

Potatoes are grown in rotation with other crops and are generally planted on land that has been in grass the previous year. The land is ploughed to a depth of 9 to 10 in. in late winter, and farmyard manure is applied in the drills at the rate of 15 to 20 tons per acre at the time

of planting. Artificial manure is sown at the same time at the rate of 6 cwt. per acre. This is compounded so as to give on analysis $6\frac{1}{2}$ per cent nitrogen, 20 per cent phosphates, and $5\frac{1}{2}$ per cent potash.

The varieties grown are Epicure and Ninetyfold. The seed is usually cut, and from 14 to 16 cwt. are required to plant an acre.

The drills are drawn 28 in. wide, and the sets are laid 12 in. apart in the drill. One man and one horse will scarify, drill, harrow, and plough up 1 ac. in one day.

Raising of the crop begins in the third or fourth week of June, and the average yield at the beginning of the season is about 5 tons per acre. Crops are generally cleared before disease does any damage, and Savoy cabbages are frequently grown as a catch crop after the potatoes are lifted.

**Ayrshire Practice.**—Ayrshire is the chief centre of the industry in Scotland, and it may well be asked why this county should have attained such prominence in the production of a crop which is so liable to suffer damage from frost and storm. It has few natural advantages. The soil is in many cases poor, and the land is exposed to the full blast of the storm from the Atlantic Ocean. It has been suggested that a current from the Gulf Stream strikes the coast at this particular point and moderates the temperature, but this theory is not supported by the reports of the Meteorological Society. According to them the temperature does not vary much as between the east and west of Scotland. The only marked difference is in the rainfall, which runs from 23 to 25 in. in the east, and from 38 to 40 in. in the west. The mean temperature in both east and west is around 48° F.

**Acreage.**—The area under the crop extends from Ballantrae in the south to West Kilbride in the north of the county, a distance of about 50 miles along the seaboard. The width of land available for the crop varies from 100 yd. to, in some cases, half a mile or more from the seashore. The soil ranges from drifting sand to medium loam.

The estimated acreage of the crop annually grown in the county is about 8000 ac., and potatoes have been grown on the same land from thirty to fifty consecutive years.

## Cultivation in Ayrshire.

**Manures Applied.**—Large quantities of seaweed are washed ashore during the autumn and winter months and spread on the land at the rate of 30 to 40 loads per acre, and dung, brought from Glasgow and other centres, is applied at the rate of 12 to 15 tons per acre. An effort is made to alternate the application where both are available, but it is seldom that both dung and seaweed are applied to the same land in the same year.

Attempts have been made to produce crops without either dung or

seaweed, but these attempts have not been attended with a great measure of success, especially in seasons when the rainfall happens to be under average. Where either dung or seaweed has been applied, the crop does not suffer to the same extent during a time of drought, and no application of artificial manure will make up for this want. It is probable that one of the chief reasons why Ayrshire has attained to its present position as a potato-growing county is because of the large quantities of dung applied to the land.

In addition to farmyard manure and seaweed, artificial manure is applied at the rate of 11 to 12 cwt. per acre at the time of planting the seed. This manure is frequently compounded on the farms, and consists of sulphate of ammonia, superphosphate, potash, and in addition bone flour or Liebig guano to act as a drier. This mixture will give on analysis $7\frac{1}{2}$ to $8\frac{1}{4}$ per cent nitrogen, 18 to 20 per cent phosphates, and about 3 per cent potash. A larger percentage of potash may be advantageously applied where seaweed is not obtainable.

**Preparatory Cultivation, Manuring, and Planting.**—Preparation for the crop begins in October, when dung and seaweed are spread on the land and ploughed in during the winter to a depth of 9 or 10 in. This work is usually completed about the end of January, and planting begins as soon after the middle of February as weather conditions permit. At this season of the year great patience is often required on account of the fickle nature of the climate. Quite frequently the land is not in condition for cultivation for weeks together, and nothing tends so much to cause failure as to work on the land when it is wet. It may not be considered economical to keep horses standing idle, but it is oftentimes more profitable to have both men and horses idle than have them working on the land when it is not in order. A single turn of the harrows is generally sufficient to make the land fit for drilling. When the land is suitable and has been properly ploughed, the less treading the better will be the chance of a good crop. Treading only tends to solidify the soil, and the potato loves freedom for root expansion.

The drills are drawn 25 in. wide, and when possible across the plough furrows, with a combined plough and manure sower. The use of this implement ensures that the drills are uniform in depth and have no hoof marks into which the seed is apt to roll. The sets are laid by hand at a width not exceeding 12 in. in the drill.

The manure is sown by the combined plough and manure sower, and may either be dropped in the bottom or spread over the drill, although it is not desirable that the manure should come into close contact with the sets. A short chain attached to the sole of each plough and drawn along will mix the soil and manure sufficiently to prevent damage to the seed.

Three pairs of horses harrowing, drilling, and covering the seed, one

horse carting out seed and manure, together with nine women laying the sets out of boxes, will plant from 5 to 6 ac. per day.

**Selection and Storage of Seed.**—When the crop is being lifted medium-sized sets are selected by hand, stored in boxes, and put away for the following year's crop. In purchasing or selecting seed, care should be taken to ascertain that the stock is reasonably true to name and free from disease or leaf curl. No seed should be accepted without a guarantee, and where possible the crop from which it is to be selected should be seen growing. This can be more easily managed than in the case of late potatoes, as the bulk of the seed is raised before maturity and while the haulms are still green, so that "rogues" and disease can be more easily detected.

The most popular size of seed weighs from $2\frac{1}{2}$ to 3 oz. per set, and from 28 to 32 cwt. are required to plant an acre.

The practice of sprouting the seed is now almost universal. The selected seed should be as uniform in size as possible and stored in boxes immediately they are raised. It may with advantage be exposed to the weather till the tubers are greened, but this procedure tends to reduce the life of the boxes. The usual practice is to place the boxes at once in the house in which they are to remain during the winter. The boxes most commonly used contain 42 to 48 lb. and are of a standard size measuring, inside, 2 ft. $5\frac{3}{4}$ in. long and 1 ft. $7\frac{3}{4}$ in. wide. The depth is 3 in., with corner pieces $6\frac{1}{2}$ in. high with handles attached for carrying. When stored in tiers there is a clear space of $3\frac{1}{2}$ in. for light and air between the top of the potatoes and the bottom of the box immediately above. The boxes may be built up on the top of each other to a height of 10 to 12 ft.

Most of the houses for storing the seed have been converted from other uses, and are not as suitable as a few which have been specially built for the purpose. The most essential requirement is light, and in order that the best results may be obtained it is necessary not only to have a well-lighted house, but also to have a clear space of 15 in. between each tier of boxes. Where this cannot be done it will be necessary to turn the boxes round once or twice during the winter and spring months, otherwise the seed will be very irregularly sprouted and the stems too tender to stand handling at the time of planting.

An early crop depends more on the careful handling of the seed, both before and at the time of planting, than on almost anything else. Success to a large extent depends on the uniformity of the plants, and where this is absent the later plants are either sacrificed or the harvesting of the whole crop is delayed till the more backward plants mature. The principal object in storing seed early in the season is to ensure that the first bud is protected from injury. Whether the tubers are large or small, only one stem comes away in the first instance, and the protecting of this from injury ensures that the full strength of the tuber is conserved

for the growth of the plant. Where it is intended to cut the tubers the first bud must be broken off, after which a sprout will spring from several or all the eyes of the potato.

**Varieties Grown.**—About twenty years ago, or from 1900 to 1906, a considerable number of varieties were grown, the principal being Puritan, Nonsuch, May Queen, Ruby Queen, Ninetyfold, Goodrich, Dalmahoy, Don, Harbinger, Sutton's Regent, Sutton's Seedling, and Fiftyfold. About that date the Epicure was introduced, and after a few seasons' trial nearly all the other kinds were discarded in its favour. Its principal characteristics are its hardiness, the rapidity with which it recovers from injury caused by frost or storm, and its ability to produce a heavy crop of marketable potatoes of reasonably good quality. The cultivation of this variety does not obtain to any great extent beyond the county, and a change of seed is practically confined to its boundaries. The differences of soil and climate, however, even within these narrow limits, are such that thus far the vigour of the plant has been maintained to a much greater extent than has been possible with many of the other varieties in cultivation.

**Treatment during Growth.**—Towards the end of April the young shoots appear above the ground, and a light harrow is passed over the drills in order to kill as many of the annual weeds as possible. After this, the land is cultivated between the drills, and hoed by hand labour. At a late stage the land is drill cultivated as deeply as possible, and, immediately before the haulms meet in the drills, a moulding up plough is used to complete the work.

**Lifting and Marketing.**—In an average season the crop is ready for lifting about the middle of June, and it is marketed in increasing quantities till the end of July. Crops grown on sandy soils mature earlier and as a rule do not produce so heavy a yield. They are lifted first, leaving the crops on the better soils till they are more matured. The demand is generally keener early in the season; prices are also higher then, and it is not usual to wait for a maximum yield. As soon as the tubers reach a marketable size a start is made, and the growth is so rapid that every day shows a marked improvement. The yield about the beginning of the season may average only about 5 tons, and later on run to 12 or 16 tons per acre.

The crop is sold growing, either by auction or privately, to potato merchants. Very few farmers market their own crop. The practice has almost become general for growers to invite merchants to attend at the farms on a certain day when the crop is nearing maturity; it is then sold in lots of from 5 to 20 acres in extent, the merchants taking all risk from the date of the sale.

Merchants buy on the same farms year after year and can estimate fairly accurately how many tons a growing crop will yield per acre. They

also provide the labour for lifting the crop, and for this purpose large numbers of workers, both male and female, are brought over from Ireland annually. These workers receive accommodation at the farms where they are for the time being employed, and are allowed as many potatoes as they can use and also coal for cooking. They work in gangs of twenty to thirty with a foreman over each gang. One worker, who may be either a man or a woman, throws out the tubers with a hand fork, while another gathers and assorts them according to size in the different baskets. Six or seven pairs of workers are expected to dig, gather, and assort an acre per day. The plants are usually growing closely together, and care is necessary to avoid cutting the tubers with the fork. Carelessness in this frequently entails considerable loss, as the damaged tubers are only fit for cattle food.

Ordinary potato-digging machines have been used in emergencies for lifting the crop, but the potatoes, being at that time soft and tender of the skin, are liable to be damaged by the revolving forks. The rank haulms are also a hindrance, but possibly the greatest objection to the machines is the difficulty of supervision, as the workers are scattered over a much wider area than in the other case. This specially applies to sizing and assorting the crop for market.

The grower carts the produce in bags or barrels to the nearest railway station, from which it is dispatched to the different markets. The principal markets are the large cities and industrial centres throughout Scotland and the north of England, and, on occasions, supplies are sent to Manchester and even as far south as London. About one-third of the early potatoes grown in Ayrshire are marketed in England. During the green-sale season of 1920 the quantity dispatched by rail from stations between Pinwherry and West Kilbride was 61,375 tons, and of this quantity 22,664 tons crossed the border into England. In addition to this a considerable quantity of seed was sent south later in the season.

Few growers ever attempt to spray their crops. They prefer to get them away early enough to avoid the risk of disease, but in wet seasons losses do take place from this cause. Probably the most serious loss occurs when the crop is lifted in a semi-green state, and seed taken from such a crop, when disease is prevalent, is very liable to go bad in the boxes. 25 to 50 per cent of loss is not uncommon under such circumstances. Wart disease is almost unknown to early growers.

**Cost of Production.**—In 1914 the cost of producing a crop of early potatoes was estimated at £24 to £28 per acre. Prices have recently fluctuated to such an extent that it is difficult to give corresponding figures applicable to the present time (1924). Labour, certain kinds of manure, and seed have cost three times what they did, and meantime it would not be safe to reckon the cost at less than two to two and a half times that of pre-war days. In 1921 the cost per acre would range from £55 to £63 per acre.

In the year 1896 the crop on three farms was sold by auction at prices ranging from £11, 2*s.* 6*d.* to £22, 10*s.*, while on other three farms in the same season the prices realized were from £13, 15*s.* to £32, 5*s.* per acre. 322 ac. were sold in 57 lots, and the average price was £19 per acre. The newspaper report of the sale stated that the crop looked remarkably healthy and was sure to raise well. Ten years later (1906) prices ranged from £17 to £36, 10*s.*, and the average was slightly over £24 per acre. In the year 1910 about 400 ac. were sold by auction and realized £27 per acre. In 1915 prices mounted up to £33 per acre, and it is a noteworthy fact that in August of that year, or one year after the beginning of the Great War, potatoes were loaded on rail at 30*s.* to 35*s.* per ton, which was the current price for good ware at the time. In 1917 about 750 ac. were sold by auction at an average price of £93, 10*s.* per acre. Prices reached the climax in 1920, when 14 ac. were sold by public auction at the record price of £181 per acre, or four times the value of the land on which the crop was grown. Other lots were sold at correspondingly high figures. Merchants lost heavily, and more than one firm, unable to stand the strain, was forced into liquidation. The inevitable reaction took place during season 1921. Prices were in most cases less than half of the previous year, and some growers had to accept less than the cost of production, while 1922 brought no improvement.

One is frequently asked as to the prospects for the future. Anyone who is rash enough to give a decided opinion on this subject has only to be reminded of past experience in order to shake confidence in prophecy. It is not safe to predict as to either crop or prices very far ahead. A night's frost or a spell of drought is liable to upset all calculations.

**Catch Cropping.**—When the crop is lifted in June, and even up to the end of July, it is customary to sow a catch crop, such as green kale, barley, rape, or Italian Ryegrass.

Green kale is sent to market for human consumption, but the demand is limited, and it only commands a ready sale when other green stuffs, such as cabbage, are not obtainable.

Barley has, in some early seasons, attained a sufficient state of ripeness to be thrashed, the grain being used either for feeding purposes or malting. In general, however, the crop is cut green and used for forage. Dairy cows thrive remarkably well on it, and coming as it does when green food is scarce, it is much appreciated by dairymen.

Oats have been tried, but only on rare occasions has the crop been a success. Eel-worms consume the young plants in the early stages of growth, and where a mixed crop of barley and oats has been tried the barley has grown to maturity while the oats were completely devoured.

Rape is sometimes grown, and while it has the advantage of costing little for seed, it can only be grown once in about five years on account of its susceptibility to finger-and-toe disease. A good crop of rape is

invaluable for feeding sheep; nothing will feed a lamb quicker, and from 15 to 20 head may be fattened off each acre if the crop is good.

Italian Ryegrass as a crop is expensive to seed, about 3 bus. being required per acre. It has the disadvantage of not being able to keep down the annual weeds which spring up and grow luxuriantly where the land is in a high state of fertility. A good crop will fatten from 6 to 10 sheep per acre, and the fibrous nature of the roots makes soil conditions ideal for the growth of future crops.

# THE POTATO CROP

By Professor R. G. WHITE, M.Sc., N.D.A.(Hons.)

The potato (*Solanum tuberosum*, L.) is a native of the higher and cooler districts of Chile and Peru, where it is found growing in dry, elevated valleys removed from the seaboard. Evidence points to its having been cultivated there from early times, and to its having been spread by native cultivation as far north as North Carolina and Virginia before the discovery of the New World. Spaniards appear to have taken the plant to Europe from Peru about 1530, and whilst it seems to have been first grown in the British Isles in the last decade of the sixteenth century, there is doubt as to whether it was introduced from Virginia by the Raleigh expeditions or captured from Spanish vessels by Sir Francis Drake.

The genus to which the plant belongs is a very large one, and includes five other species, viz. *S. Commersonii*, *S. Maglia*, *S. cardiophyllum*, *S. Jamesii*, *S. oxycarpium*, which bear tubers. These, as yet, are of no agricultural importance, though attempts have been made to improve them, and to utilize them in breeding new varieties, particularly in the case of Commerson's potato (*S. Commersonii*) and Darwin's potato (*S. Maglia*).

The beginning of the seventeenth century was a period of advance in British agriculture, and among other developments the cultivation of potatoes as a field crop was suggested, but it was not until the eighteenth century that cultivation became general. Indeed, during the former period, the virtues of the potato were not appreciated, for in 1664 Evelyn recommends them to be planted in the worst ground and in 1716 Bradley states that they are inferior to radishes. The middle of the eighteenth century, however, marked the beginning of a great onward movement—land was enclosed, the cultivation of turnips became general, the Norfolk four-course rotation was evolved, and Tull's system of drill husbandry was applied to the growing of root crops. In this advance potatoes for the first time came into general cultivation as a field crop. Doubtless the need

for securing the greatest possible amount of food during the Napoleonic wars caused more attention to be paid to the crop, just as a similar need did a hundred years later.

For a long time the new crop was regarded with suspicion, particularly by landowners, and at the end of the eighteenth century a common condition of leases was a clause stipulating that no more than a very small acreage should be planted with potatoes. For instance, the following occurs in all the leases granted on a large Yorkshire estate about this time:

> " Also not in any one year to plant with potatoes any greater quantity than one acre and a half of ground; and that in the same field sown or intended to be sown with turnip seed and no where else."

Such conditions were commonly imposed throughout the nineteenth century, and no doubt many farms are still held nominally on such conditions, though special agricultural legislation has taken the sting from such restrictive clauses. To some extent they had their origin in the general idea that potatoes were an exhausting crop, but, underlying them, is also the fear that potatoes would be grown mainly at the expense of root crops, and as, in most cases, they would be sold off the farm, the number of stock kept and the amount of dung made would be seriously reduced, to the detriment of the general fertility of the farm. In spite of such discouragement the cultivation and economic importance of the crop increased to a great extent.

Meanwhile various diseases became evident amongst the crops. " Curled leaf ", first observed about 1792, increased with such severity that, in 1831–2, it caused a great deal of devastation. Later, the advent of blight, then known as murrain, in 1835–6 gave rise to increasing potato-growing losses which in 1845–6 culminated in famine in Ireland and the Western Scottish Highlands. This unfortunate drain on wealth stimulated interest in the production of more vigorous potatoes, less susceptible to disease, and by the end of the century, although disease pestilence had not been destroyed, it had at least been curbed. Associated with this work are several outstanding raisers and growers. Of these the most noted are Mr. William Patterson, of Dundee, the raiser of the Victoria, for long a prized variety; Mr. John Nicoll, Ochterlony, raiser in 1867 of the Champion, which is still grown to a small extent; Messrs. Sutton, introducers of Magnum Bonum, Abundance, and many others; and Mr. Findlay, of Markinch, raiser of the Bruce (1887), Up-to-date (1893), British Queen (1894), and many other well-known varieties. During the present century, such great interest has been shown in the development of the potato that it would be impossible in such an article as this, either to review all the work carried out or to mention all those associated with it.

The importance of the crop in recent years is shown in the following table:

Acreage of Potatoes

| Year. | England and Wales. | Scotland. | Ireland. | Total. |
|---|---|---|---|---|
| | Acres. | Acres. | Acres. | Acres. |
| 1871–1875 | 382,029 | 167,880 | 957,279 | 1,507,188 |
| 1895–1904 | 423,156 | 129,758 | 657,878 | 1,210,792 |
| 1905–1914 | 434,949 | 144,060 | 593,560 | 1,172,569 |
| 1915 | 463,399 | 144,393 | 594,467 | 1,202,259 |
| 1916 | 427,948 | 130,119 | 586,308 | 1,144,375 |
| 1917 | 507,987 | 147,717 | 709,263 | 1,364,967 |
| 1918 | 633,832 | 169,497 | 701,847 | 1,505,176 |
| 1919 | 475,376 | 154,596 | 588,802 | 1,218,774 |
| 1920 | 544,615 | 162,477 | 584,316 | 1,291,408 |
| 1921 | 557,800 | 153,820 | 568,091 | 1,279,711 |
| 1922 | 561,177 | 157,404 | | |

From the above it will be seen that, with the exception of the period affected by the war, the area in Great Britain has remained fairly constant since 1890, the fact being that the area grown in most years is just about sufficient to meet the needs of the consuming population. Improved methods of manuring, cultivation, and the growing of more productive varieties have been sufficient to give in normal years an increase of crop sufficient to keep pace with the demands of the increasing population.

Such in brief is the history of the development of the potato crop in Great Britain. During the latter half of the eighteenth century and the first half of the nineteenth century it developed from a position of insignificance to that of a food crop second only in importance to the cereals, and for many years it has occupied the position of being the only important food crop in which the British Isles are self-supporting.

**Distribution of the Crop.**

While potatoes are grown on practically every farm and in every garden in Great Britain, the districts which produce the bulk of the supplies for the large markets are comparatively limited, and fairly clearly defined, as is shown in table for 1914 on the following page.

The areas in which potatoes assume the greatest importance are as follows:

1. The Fen districts surrounding the Wash, including parts of Lincolnshire, Cambridge, and Huntingdon, and to which a limited area of Norfolk may be added. Although in this case the area is remote from large markets, the eminent suitability of the soil and climate for the crop is more than

| County. | Area of Potatoes. | Total Area of Arable Land. | Proportion to Arable Land. |
|---|---|---|---|
| | Acres. | Acres. | Percentage. |
| Lancashire .. .. | 45,826 | 236,220 | 19·3 |
| Lincoln (Holland) .. | 43,686 | 179,033 | 24·4 |
| Isle of Ely .. .. | 31,915 | 161,922 | 19·7 |
| Yorkshire (West Riding) | 25,815 | 341,755 | 7·5 |
| Cheshire .. .. | 24,403 | 191,210 | 12·7 |
| Forfar .. .. .. | 18,293 | 219,930 | 8·3 |
| Fife .. .. .. | 17,784 | 172,158 | 10·3 |
| Perth .. .. .. | 17,341 | 225,775 | 7·6 |
| Stafford .. .. .. | 12,372 | 151,236 | 8·1 |
| Durham .. .. | 12,120 | 140,379 | 8·6 |
| Huntingdon .. .. | 10,567 | 122,013 | 8·6 |
| Ayrshire.. .. .. | 10,053 | 143,678 | 6·9 |
| East Lothian .. .. | 9,178 | 89,617 | 10·2 |
| Midlothian .. .. | 7,511 | 78,675 | 9·5 |
| Renfrew .. .. | 3,336 | 35,913 | 9·2 |
| West Lothian .. .. | 2,753 | 33,498 | 8·0 |
| Dumbarton .. .. | 2,530 | 24,000 | 10·5 |

sufficient to counterbalance the cost of transport to London and the large markets of the Midlands and the North.

2. A somewhat similar area, though much more restricted in extent, and not clearly shown in the above table, exists in the parts of Yorkshire and Lincolnshire adjoining the Ouse and Humber. This area, though more favourably situated as regards markets than the Fen district, again probably owes its importance as a potato-growing area mainly to the suitability of the soil and climate.

3. Lancashire and Cheshire grow a large area, and in this case the immense industrial population provides a remunerative market at a distance of only a few miles from the farms. In the same way proportionately large areas in the counties of Kent, Stafford, Surrey, Warwick, and Worcester are chiefly attributable to the proximity of large markets. None of the Welsh counties approaches the 10 per cent figure in spite of the good markets of South Wales. This is apparently due to large imports from Ireland.

In Scotland potatoes are of especial importance from the point of view of the trade in " seed ", which will be dealt with later. Except for Ayrshire and parts of Wigtownshire, which are largely concerned in the early potato industry, and Dumbartonshire, Lanarkshire, and Renfrewshire, which have a ready market in the industrial areas of Clydeside, the chief potato areas are in the east, and in many respects the cultivation of the

crop in the Lothians, Fife, and Forfar attains an importance hardly exceeded elsewhere.

On the whole, therefore, it will be seen that the chief potato-growing districts are on the east of Great Britain rather than the west, the reason for this being the drier, more sunny climate, and the occurrence in certain areas of particularly suitable soils.

## The Importance of Potatoes as a Food Crop.

Reference has already been made to the fact that Great Britain, with the assistance of the surplus of the Irish crop, is self-supporting as regards potatoes. In fact, before the war it was by no means uncommon for considerable quantities to be exported to the United States and other countries when a bad season and high prices abroad happened to coincide with a glut and low prices at home. For instance, in 1912, 360,000 tons were exported. Of these over 300,000 tons were sent to the United States, the difference in values on the two sides of the Atlantic being sufficient to pay shipping charges and import duties. Such a large export is, however, exceptional, and on an average exports about balance the imports, which usually consist mainly of early potatoes, but in bad years may include a large proportion of other varieties for the ordinary winter market.

An investigation was carried out by a sub-committee of the Royal Society during the war to ascertain more exactly than had hitherto been done the average composition of British-grown potatoes. The average composition of 247 samples of washed potatoes was 22·09 per cent dry matter, including 0·327 per cent nitrogen. Considerable difference existed between different varieties and also between potatoes from different parts of the country. Generally speaking, tubers grown in the eastern areas had a higher percentage of dry matter and nitrogen than those grown in the wetter western districts.

As compared with other crops potatoes produce the heaviest weight of human food per acre of all the crops commonly grown in this country. The only other farm crop which surpasses it is sugar beet. Without going into too much detail or using scientific methods of comparing food values, it may be pointed out that on soils suited for the cultivation of the respective crops, it is probably as easy to grow 8 tons of potatoes per acre as 5 qr. of wheat. 8 tons of potatoes contain nearly 4000 lb. of dry matter, and 5 qr. of wheat less than 2500 lb. The comparison is only a rough and ready one, but the dry matter in the two crops is of sufficient similarity to make the method fairly accurate. From the national point of view the crop is, therefore, of special importance, though it has the disadvantage of being a bulky crop, expensive in transport, and subject to serious losses in storage, where it cannot be kept for more than a few months. From the farmer's point of view the crop has the disadvantage

of being a comparatively uncertain one, as is shown by the average yields given in the Government returns quoted in the following table.

AVERAGE ESTIMATED YIELD PER ACRE AND TOTAL PRODUCTION IN GREAT BRITAIN

| Year. | Average Yield per Acre. Tons. | Total Production. Tons. |
|---|---|---|
| 1890 | 5·31 | 2,811,785 |
| 1891 | 5·73 | 3,053,461 |
| 1892 | 5·80 | 3,048,733 |
| 1893 | 6·59 | 3,476,328 |
| 1894 | 5·53 | 2,788,983 |
| 1895 | 6·64 | 3,592,619 |
| 1896 | 6·32 | 3,562,235 |
| 1897 | 5·17 | 2,608,193 |
| 1898 | 6·26 | 3,282,517 |
| 1899 | 5·62 | 3,076,721 |
| 1900 | 4·87 | 2,734,980 |
| 1901 | 6·36 | 3,671,250 |
| 1902 | 5·57 | 3,194,188 |
| 1903 | 5·16 | 2,913,713 |
| 1904 | 6·29 | 3,588,254 |
| 1905 | 6·18 | 3,762,706 |
| 1906 | 6·06 | 3,428,711 |
| 1907 | 5·42 | 2,977,485 |
| 1908 | 6·97 | 3,917,618 |
| 1909 | 6·39 | 3,674,453 |
| 1910 | 6·44 | 3,477,139 |
| 1911 | 6·69 | 3,825,312 |
| 1912 | 5·19 | 3,179,632 |
| 1913 | 6·54 | 3,865,458 |
| 1914 | 6·57 | 4,030,688 |
| 1915 | 6·30 | 3,830,177 |
| 1916 | 5·44 | 3,035,535 |
| 1917 | 6·79 | 4,451,080 |
| 1918 | 6·7 | 5,360,000 |
| 1919 | 5·7 | 3,565,000 |
| 1920 | 6·2 | 4,388,000 |
| 1921 | 5·1 | 3,998,000 |

The actual fluctuations on any particular farm, or even in a given district, are much greater than is shown in the table, which relates to the country as a whole, and covers such a wide area that there are, as a rule, sufficient exceptions to a season's results to keep the average close to normal. Furthermore, the high cost of production and susceptibility to various diseases involve a heavy risk which, in years favourable to the

growth of large crops, with consequent glutted markets and low prices, proves sometimes disastrous to those at a distance from good markets.

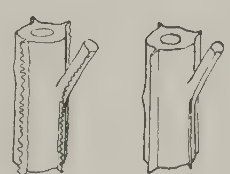
Improved methods of cultivation, control of diseases, and introduction of improved varieties will doubtless in time make it possible to reduce the cost of production. But the possibility of a permanent substantial increase in the acreage depends on whether a suitable outlet, at remunerative prices, can be found for the surplus in a year when a superabundant crop has been grown.

## Botanical Description of the Potato Plant.

The potato belongs to the natural order *Solanaceæ*, which embraces a large number of plants chiefly found in tropical and subtropical regions. The tobacco and tomato plants also belong to this order, and such common British poisonous weeds as Bitter-sweet (*Solanum Dulcamara*), Black Nightshade (*S. nigrum*), Deadly Nightshade (*Atropa Belladonna*), and Henbane (*Hyoscyamus niger*).

**The Seed.**—The true seed is very small and flattish oval in shape. It consists of a seed coat enclosing a store of food material called " endosperm " embedded in which is an " embryo ". The embryo is that of a typical dicotyledon, consisting of two " cotyledon leaves ", a " plumule bud ", and a " radicle ".

**The Seedling.**—When the seed germinates in soil the radicle grows downwards to form the primary tap-root, whilst the cotyledons, raised by growth above the surface of the ground, become the first green leaves of a small size and ovate shape, and the plumule bud gives rise to a leaf-bearing stem or shoot. The primary root continues its growth down through the soil, producing many branches as it lengthens, and the stem, giving off compound leaves at thickened portions, termed " nodes ", grows upwards. That part of the stem between the nodes is termed the " internode ".

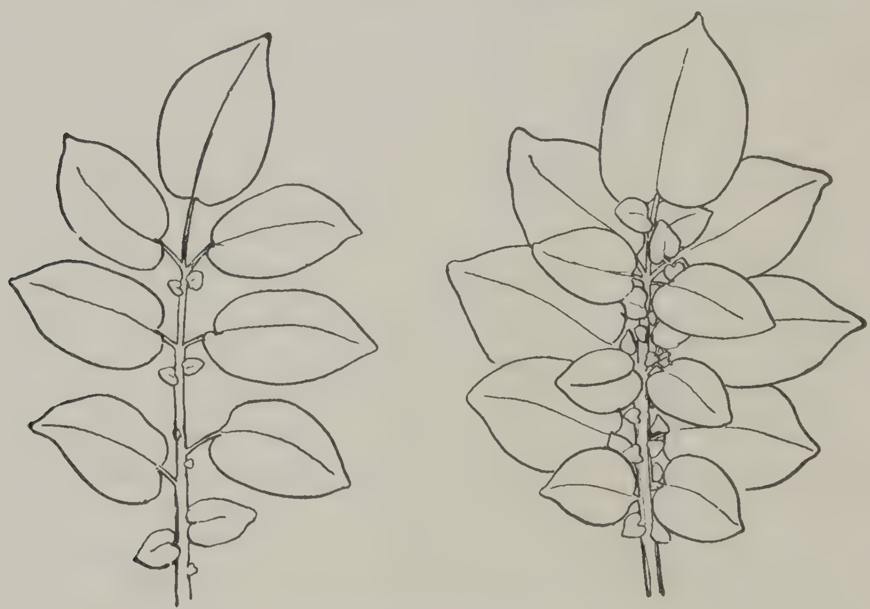


Segments of stems showing straight and crinkled wings.

The stem of the seedling, like that of mature plants, is of a herbaceous nature and is usually hollow. In shape it is somewhat triangular, and bears projections which run in a longitudinal direction and are commonly termed " wings ". These may be either smooth and straight or wavy and crinkled. The stem is occasionally branched, each branch exhibiting the characteristics of the main stem. The leaves borne on the stem by stalks, known as petioles, are pinnately compound and consist of a variable number of pairs of large and small leaflets termed secondary leaflets. These alternate with each other along the main rib which terminates in an unpaired leaflet. The stem with its leaves is called the " haulm " or " shaw ".

At a comparatively early stage branch shoots, arising in the axil (angle

between leaf and stem) of the cotyledons, grow down into the soil which they pierce in a horizontal direction, thereby forming underground stems or runners. The latter, which are usually short, bear rudimentary leaves called " scale leaves ", in the axils of which originate branch runners. After the formation of a few internodes, both the branch and main runners become greatly swollen to form " tubers ", the nature of which will be presently described more fully. Tubers from seedling plants are usually very small, but through propagation for four or five years they gradually attain their normal size. In addition to the primary root the seedling is



Open and close leaves showing secondary leaflets

provided with a profusion of small roots which originate from the nodes of the underground runners. These are termed " adventitious " roots. Such are the *only* roots found in plants propagated from tubers. When the stem has attained its full size, flowers are usually produced; this, however, is not always the case, as many varieties have not been observed to produce flowers. The term " inflorescence " is applied to the floral system and, since the main axis terminates in a flower, the inflorescence is called a " cyme ". Each flower consists of four successive whorls of distinct parts. On the outside there are five green sepals, joined at their bases but free at their tips. These, in the young state, protect five petals of variable colour, which are joined throughout and which support the next " whorl " of five stamens, bearing on their stalks or filaments small yellow cases of pollen termed " anthers ", which release their pollen through pores at their tips. The colour of the petal is very variable. Common colours are white, mauve, heliotrope. The centre of the petal is often coloured whilst the margin is white. In the centre is a structure, apparently cylindrical, termed the " ovary ", which is formed from the fusion of two

carpels, the innermost whorl of floral leaves. This ovary consists of two chambers which contain " ovules " attached to a placenta formed from the junction of two ovary walls in apposition. Projecting from the top of the ovary is a small stalk called the " style ", which bears a flattened bifid tip called the " stigma ". This serves to receive and retain pollen derived from the anther. The base of the ovary rests upon the inner edge of other floral parts, and thus the ovary is said to be superior in origin.

**Fruit.**—After fertilization has been effected by the fusion of elements derived from the pollen and the ovules respectively, the whole of the flower, with the exception of the original ovary, degenerates. It, however, matures into the fruit, which is a " berry " and commonly termed the " plum ". This is soft and succulent and bears true seeds attached to a central placenta. When extracted from the berry each seed may produce a new plant as described above. Many varieties—often the most prolific—produce neither flowers nor fruits, whilst others produce flowers but no fruits. Flowering and fruiting, in some instances, may be encouraged by plucking off early formed tubers.

The *tuber* is simply a swollen part of the underground stem, consisting of nodes and internodes, spirally arranged, bearing scale leaves and buds at an early stage. It never bears adventitious roots. The part of the tuber to which the runner was originally attached is termed the " heel ", while the morphological growing point is termed the " rose " end. The buds are arranged in clusters usually of three, in areas surrounding depressions called the " eyes " of the tuber, which are really lateral branches with undeveloped internodes. There is a greater profusion of eyes at the rose end than at the heel, since the internodes are here shorter. Depth of eye and shape of tuber vary according to variety (see " Quality "). In some cases when growth has been checked by drought and renewed by rain at a later date, instead of the tuber enlarging in the ordinary way, one or more growths proceed from the eyes when " supertuberation " or " second growth " is said to exist. This second growth may even take the form of runners originating from the tuber. Certain varieties have a tendency to exhibit this undesirable characteristic. If a potato should be prevented from maturing tubers underground by picking them off as formed, or if a potato be sprouted in a damp, darkened room, green aerial tubers will be formed in the axils of the leaves.

The tuber shows all the characteristics of an ordinary shoot. On its outside is a skin, termed the " epidermis ", on which are seen innumerable breathing pores called lenticels. These allow of the entrance of fresh air for the living cells within, and of the exit of waste gases resulting from respiration. Within the skin are the same tissues as are found in all stems with the exception that the cells are principally used for storage purposes. The carbohydrates, formed by the process of " photosynthesis " in the leaves, are carried down to the tubers in which they are stored as starch.

Thus the tuber is used by the plant to conserve its food supplies. On exposure to light it assumes the green colour of ordinary stems, hence the necessity for deep " earthing up " in cultivation.

However, it has another important function, for it gives to the plant its perennial character. Under natural circumstances the green shoot dies down at the end of the growing season, and the tubers formed in the soil produce foliage from their buds in the following seasons. This phenomenon is utilized in the cultivation of the potato; the tubers are lifted at the end of each growing season and protected from frost, to the destructive effects of which they, as succulent stems, are naturally susceptible; in the following season, on being planted under suitable conditions, each tuber gives rise to a new plant. Indeed, if the tuber be so cut and planted, each eye of the tuber can give rise to a fresh plant. Tubers used for the production of new plants are commonly called " seed potatoes ", since they give rise to new plants, but it must be remembered that the word " seed " as here used is misleading from a botanical point of view.

Plants raised from tubers show the same features as those raised from seed with the exception that there is no tap-root, the tubers are much larger, and the yield is greater.

It should be noted that before the tuber can produce new plants it must undergo a period of rest, and that, since the planting of tubers of any variety merely extends the life of that variety from year to year, it is impossible to raise new varieties in this way unless the extremely rare occurrence of "sporting" takes place (see Improvement of Cultivated Plants, Vol. I).

## Field Cultivation of Potatoes.

Potatoes are cultivated on a field scale in every county of Great Britain, but, as already mentioned, the areas in which they are grown to a great extent are comparatively few in number, the extent of cultivation being principally determined by soil, climate, and facilities for transport and marketing. The potato crop is an expensive one to grow, incurring, as it does, heavy expenditure on seed, labour, and manure. Although thoroughness of cultivation varies in different districts, it can safely be said that there is comparatively little difference between the cost of growing potatoes in a district where 6 tons per acre would be regarded as a good crop and those districts in which 8 or 9 tons are obtained with comparative ease. Naturally, therefore, in normal times the crop is cultivated mainly in those districts where soil, climate, &c., make it possible to grow with good management a reasonably heavy crop in most years, while those districts not so favoured as regards soil and climate grow only sufficient for the needs of the immediate neighbourhood.

**Climate.**—Generally speaking, potatoes do best in a comparatively dry, sunny climate, provided that the soil is able to keep them supplied

with sufficient moisture during June, July, and August, when the tubers are forming and developing.

Heavy crops are often obtained on well-drained soils in wet districts, but cultivation in such areas is usually difficult and laborious. The heavy winter rainfall makes it difficult or impossible to carry out the preliminary cultivation, which must be completed in early spring where a considerable area has to be planted; a moist atmosphere, with frequent warm rains during July and August, encourages the attacks of potato disease (*Phytophthora infestans*, referred to hereafter as blight), while wet weather in autumn greatly increases the difficulty of harvesting the crop, and often leads to very serious loss in storage. These considerations explain the fact that the chief potato-growing areas in Great Britain are on the east coast, the notable exceptions being Lancashire, Cheshire, and the early potato districts of Ayrshire, which have already been referred to. The rainfall in the east is very considerably less than that of the west, and, at the same time, the soils of the Fen district and Yorkshire are, for special reasons, usually able to supply sufficient moisture to the growing plant in summer. In other dry districts of England the crop cannot be grown so successfully owing to the lack of moisture in average seasons, and it is only where the proximity of a large market makes it possible to realize a comparatively high price for the produce that potatoes occupy a prominent position in the rotation. On the east coast of Scotland the rainfall is also low, but owing to lower temperatures and special characteristics of the soil the crop does not suffer unduly from drought in normal seasons.

While it is undoubtedly true that the most satisfactory crops of potatoes are generally grown in comparatively dry, sunny districts, the question of deterioration, discussed later, must not be forgotten. As a rule, in the warmer districts of the south, potatoes deteriorate rapidly, and recourse must be had to fresh seed obtained from cooler northern districts. Recent researches suggest that this is not so much directly due to climate as to an indirect effect—the result of greater facilities for the spread of the so-called virus diseases.

The incidence of frost is an important limiting factor, which is shown by the distribution of the early potato-growing districts. Leaving the Channel Islands out of account, Cornwall and Ayrshire are the two most important areas for the growth of first early potatoes, and other coastal districts follow. In the proximity of the sea there is comparatively little danger of frosts in early summer, which make the growth of early potatoes very precarious farther inland. Many inland districts and fields, particularly in sheltered hollows or valleys, are subject to ground frosts in May and June, sometimes even later, which would cause immense damage to potatoes if they were extensively grown, while in other districts, particularly high northern areas, autumn frosts may cause serious damage before the whole of the crop is harvested. This last danger is a constant

menace to the large grower, however suitably he may be situated in other ways for the growth of the crop. Unless almost unlimited labour is available, it is often impossible to get the whole of a large area lifted before the end of October, after which time in most districts of Great Britain heavy night frosts may be experienced, and cause the loss of a large proportion of the crop.

**Soil.**—So long as the soil is well drained—and this is absolutely essential—potatoes can be grown, if cost be disregarded, on any class of soil found in Great Britain, but, as there is always the possibility of either a glut, with unremunerative prices, or of a bad season, with very small crops, the potato is only extensively cultivated on a comparatively limited range of soils, which have been found particularly suited to it.

Heavy clays of every class are of all soils the least suited for potatoes. The cost of cultivating such soils is excessive, the crops obtained are unsatisfactory both in yield and quality, and in a wet autumn it is impossible to secure the crop in good condition.

Similarly, thin soils, overlying rock, are quite unsuited for potatoes, which demand a relatively deep range for their roots, and require a soil which has the power of retaining sufficient moisture to satisfy their needs during dry summer weather.

The best soils, combining ease of cultivation, ability to retain and supply moisture to the plant, richness in plant food, and response to liberal manuring, are the deep, stoneless, silty loams of alluvial origin, found in the marsh land of the Fen district, and the warp land adjoining the Ouse and Humber. Similar land exists in smaller areas in other districts, though frequently it is in comparatively small river valleys, which, either on account of lack of drainage or of susceptibility to summer frosts, are unsuitable for potato cultivation. It may be added that, in many of these soils, the "water table" is at a depth of only 2 or 3 ft. below the surface, so that even though the summer rainfall may be insufficient to meet the needs of the crop, the presence of this water below the surface enables the plant to secure all the moisture it requires.

Next to this special class of soil may be placed sandy loams of all kinds, notably the highly fertile loams occurring on the old and new red sandstone formations. Sands, wherever they occur, have the great advantage of being well-drained and easily cultivated, though the crops obtained in a dry climate are often small and the quality not of the highest. Where, however, the climate is comparatively moist, as, for instance, in West Lancashire, and the soils can be enriched with large quantities of organic manure, sands make highly productive potato soils, as is seen in the famous Ormskirk district and elsewhere.

Gravelly soils are only satisfactory for potatoes where the climate is moist, and it is possible to enrich the soils with large quantities of organic manure.

Peaty soils form a special class. Where they have been drained they are easily cultivated, and in certain cases, as, for instance, the black soils of the Fen district and the peaty areas of East Lancashire, they produce heavy crops of potatoes, which may be grown with comparatively little expense on manures. The quality of the tubers from such soils is, however, always inferior, and, as a rule, black-land potatoes figure at the bottom of any potato price list. None the less, they often form one of the most profitable crops that can be grown on such soils. One difficulty in dealing with peaty soils in a wet district is that of drainage, and it is on such soils that the "Lazy-bed system" is most often adopted (see p. 28).

## Factors influencing Quality of Tubers.

Generally speaking, by a high-quality potato is meant one which, when boiled, assumes a dry, floury appearance and texture, and which cooks fairly quickly and uniformly, so that when the outside has reached the desired floury stage no part of the tuber is hard and comparatively uncooked. The colour of the cooked tuber should be as white as possible, though in some varieties of recognized high quality a yellowish tinge exists. The colour should remain good, even though the cooked tuber has been cooled down and again warmed up. The common defects of potatoes are a waxy or soapy texture instead of the dry floury character, undesirable flavours, and bad colour, most commonly a dull, dark, unattractive appearance.

Varieties differ widely in regard to these qualities, but even with the same variety the quality of the tuber will vary greatly according to the soil and climate in which it was grown. Waxy texture and dark colour of the cooked tuber can hardly be avoided in potatoes grown on heavy clays or peaty soils. Dry, floury attractive appearance is generally associated with well-drained sandy loams, and it is found that, in all markets, potatoes of the same variety from different districts are valued according to the known quality of the tubers from those districts, or in some case even from certain farms. Perhaps the most famous area in this connection is the Dunbar district of East Lothian, where a comparatively small strip of land, adjoining the coast, produces potatoes of exceptionally fine quality, most of which find their way to the London markets, where they are in great demand in hotels and restaurants on account of their capacity for retaining quality and colour even after cooling and reheating.

The term quality, as commonly used, frequently includes shape, size, and general appearance of the potato.

The shape should be regular and convenient for handling. Common varieties are round, oval, or kidney in shape, each variety possessing a characteristic form. Oval and kidney-shaped tubers are most convenient for paring and round ones possess the greatest amount of flesh relative to skin. Size is also an important factor, since smallness entails loss and

extreme largeness introduces difficulties in uniformity of cooking. Varieties vary much in the proportion of large and small tubers which they produce. The colour of the skin should preferably be light yellow or pale brown, since deeply coloured varieties usually receive a poor demand. In this respect, however, Kerr's Pink and King Edward are exceptions. The skin, which should be thin, should present a clean, healthy appearance —free from scab or roughness. The eyes should be relatively shallow, to reduce wastage in paring the tuber. Extremely shallow eyes, however, usually indicate feeble sprouts. When cut, the flesh should present an entirely solid surface—cavities, frequently found in large tubers of certain varieties, are most undesirable. The colour of the flesh should be white or pale lemon. In addition to the above features, a good quality potato should be resistant to diseases and capable of yielding heavy crops. All of these characters are largely hereditary, but they may be influenced to some extent by the nature of the soil, manuring, and weather conditions.

For instance, a crop of a kidney-shaped variety grown in a hard sun-baked clay will often be almost unrecognizable as a kidney variety, and generally speaking the characteristic shape of the different varieties is only secured in a comparatively loose soil of uniform texture, where there is little resistance to the expansion of the tubers in any direction. Similarly, it is almost impossible to market potatoes with clean, attractive skins from either clay, peat, or gravel. The reason is sufficiently obvious in the first two cases. In the case of gravelly soils, it is difficult to secure a crop from them without a certain amount of surface scab.

The scheme of manuring also influences quality. For example, whilst all forms of potash manures other than kainit give practically the same yields when applied in equivalent quantities, sulphate of potash gives fully the best cooking tubers. Excessive dressings of nitrogenous manures render the plants more liable to disease and the tubers are often of bad keeping quality. Lime and manures containing free lime have a tendency to produce common scab. Recent researches suggest that this is not, as was formerly supposed, due to a direct effect of lime on the skin of the tuber, but to its promoting rapid oxidation of the organic matter of the soil.

The nature of the season has also a pronounced effect on quality. Wet, sunless seasons accompany poor quality in respect of the tubers being unduly watery, whilst wet, warm seasons encourage disease.

### Place in Rotation.

Just as the rotations adopted in different areas vary enormously, so potatoes occupy different places in rotations according to the importance attached to the crop, and the general system of farming followed. Where circumstances are particularly favourable to the production of the crop, or where, as in the case of the Dunbar soil mentioned above, potatoes of

exceptional quality and market value can be grown, they are made the chief crop of the farm, and are taken as frequently as possible. In such cases they may occupy the ground once in every three years or even oftener. For instance, in early potato-growing districts potatoes occupy the same ground annually, and in the Dunbar district a six-year rotation, including two crops of potatoes, is followed: potatoes, wheat, clover and ryegrass, potatoes, turnips, barley.

Such rotations are, however, exceptional, and can only be followed continuously where it is possible to obtain seaweed or town manure, or where, as in the case of some of the black soils of the Fen district, farmyard manure is unnecessary.

In most cases the rotation must be arranged so as to allow of the production on the farm of sufficient farmyard manure for at least the greater part of the potato crop. One of the best of such rotations, allowing of the growth of a large acreage of potatoes, is the East Lothian one, followed in many districts of Scotland and also in some English areas: turnips or swedes, barley, clover and ryegrass, oats, potatoes, wheat.

Frequently this is shortened by taking the potatoes immediately after the clover and ryegrass, particularly where it is specially desired to give the potatoes the best chance possible. In this way potatoes occupy one-fifth or one-sixth of the total arable area.

Where potatoes occupy a less important position in the general system of farming, the most common plan is to allot them part of the ordinary root break. In a four- or five-course rotation, if one-half of the root break is thus allotted to the potatoes they occupy one-eighth or one-tenth of the arable area.

Taking the country as a whole the majority of the potatoes follow a corn crop, but, where the crop is an important one, a considerable area is grown after temporary grass. During the war, when a large area of old grassland was ploughed up, potatoes proved to be one of the most suitable crops to follow good, permanent pasture, and in some cases highly satisfactory crops were obtained for two or three years at very little outlay on manures; whereas corn crops would probably have been almost complete failures, either as a result of insect attacks or of loss in harvesting due to undue luxuriance of the early growth.

From the point of view of rotation arrangement, potatoes may be regarded as excellent cleaning crops so far as Couch and similar permanent weeds are concerned, and also as a crop which leaves the soil in excellent condition for the sowing of wheat in autumn. Even on soils which are usually regarded as too light for wheat, satisfactory crops can often be grown after potatoes.

Potatoes must be manured generously, and in spite of the old prejudice against it the crop is one generally associated with high farming, and more or less intensive cultivation, providing employment for a large amount

of labour and offering special opportunities for the display on the part of the farmer of skill, powers of organization, and business instinct.

**Preparation of the Land.**

The details of cultivation vary considerably according to the way in which the crop is grown, and also depend on the nature of the preceding crop. It is proposed, however, to discuss first the most common case—that is, that in which potatoes are grown on a field scale and follow a corn crop.

If the stubble is foul with Couch, an attempt should be made to clean the land immediately after the harvest by dragging the Couch to the surface and then collecting and either burning or carting it off. A shallow ploughing may be a necessary preliminary if the surface is too hard to admit of cultivators or drags entering sufficiently deeply. Provided that the stubble is not too foul and that the autumn is sufficiently fine, this preliminary cleaning can be completed before winter. Any short pieces of Couch left on the surface if buried deeply enough in the subsequent ploughing are not likely to cause further trouble, and it is desirable to finish the preliminary cleaning as early as possible so as to avoid an undue rush of work in the following spring. If, however, the autumn is wet, or the field particularly foul, it may be necessary to continue the cleaning in the following spring, as, although potatoes of a vigorous variety and well manured are capable of smothering Couch fairly effectively, this must not be unduly presumed.

Assuming that the land has been cleaned fairly well in the autumn, it is necessary to consider next whether farmyard manure should be applied broadcast in the autumn and ploughed in, or whether it should be reserved for spring application in the rows. Opinions differ as to which is the better plan. After weighing all the pros and cons it will be found to depend mainly on local circumstances and conditions. If, for instance, a farmer has a considerable quantity of manure made after the planting of the previous crop, it is probably better for him to apply this direct to the land in the autumn than run the risk of loss during storage throughout the winter. Again, a farmer who has a large acreage of potatoes to cultivate would get backward with his work if he left the manuring of all of them until the spring. On the other hand, where the above considerations do not apply, manuring in the rows in the spring has the advantage of concentrating the manure under the potatoes; moreover, in the case of rather heavy soils the developing potato tubers are able to grow and extend with less resistance than they would experience if there were not this loose rotting manure in their neighbourhood. The importance of preventing the loss which is unavoidable when farmyard manure is stored has also to be considered. Manure applied in autumn is generally manure made some months earlier, and before potatoes start to make use of it is

probably a year old, thereby having suffered very considerable loss during that period. Although it is not sufficiently realized, the determining factor ought, in most cases, to be this prevention of loss. There is not likely to be much manure made on the farm before Christmas, by which time it is generally desirable to have deep ploughings completed. Most of the manure made during the winter up to the potato-planting season can with advantage, therefore, be applied in the rows at planting time. Where cattle are fed indoors until comparatively late in the season the resulting manure must be kept until the following autumn, but it should then be got on to the land as soon as possible. Where practically all the farmyard manure produced on the farm is required for potatoes, part of the crop will therefore be manured in this way in the autumn, but where some of the manure is reserved for mangels or swedes, it is probably better to apply the manure in autumn to land intended for these crops, as they are more likely to suffer from drought than potatoes. The placing of fresh, strawy manure in rows in late spring facilitates drying out of the soil, and may result in unsatisfactory germination of root crops, whilst it does not so much affect potatoes.

The nature of the soil and climate play a part in this consideration. If the soil be light or if the rainfall be low it is usually advisable to apply the manure in the autumn, but if the soil be heavy or the rainfall high it is often better to apply it in the drills.

### Autumn Manuring and Ploughing.

If land is to be manured broadcast in the autumn, the Scottish plan of first marking out the ground into squares of 5 or 6 yards by means of a ridging plough fitted with a long marker is strongly to be recommended. This ensures even distribution of the manure, a small heap being placed in the centre of each square. Not only can the manure from the carts be more evenly placed out in this way, but when it is spread the extent of ground to be covered by each heap of manure is clearly defined.

Whether the land is manured in the autumn or not, deep ploughing before winter sets in is in most cases desirable. Provided that the soil is naturally deep, this ploughing can hardly be too deep, so as to ensure the greatest possible depth of loose mould on which the crop can feed, and in which the new tubers have freedom to develop. In order to prevent farmyard manure, spread on the surface, from being buried too deeply, it is advisable first of all to plough it in lightly and cross plough the land deeply afterwards, so that the manure will be within easy reach of the roots of the plants.

In certain cases it is the custom to double plough the land in order to get a greater depth than can be secured by any single ploughing, one plough turning over a furrow of 4 or 5 in., followed immediately after by another turning over the underlying soil as deeply as the latter will permit.

This, however, is rather exceptional and generally limited to cases where it is desired to bury old turf or weeds, and obviously even for these purposes it can only be carried out on particularly deep, uniform soils. *Subsoiling*, which stirs and breaks up the subsoil without bringing it to the surface, is more commonly done than double ploughing, and is a desirable means of securing a greater depth of loose soil than can be obtained by the ordinary plough.

In the following spring, as the planting season approaches, the winter furrow is broken up by harrows, cultivators, &c., and in many cases this leaves a sufficient depth of loose, free soil to enable the rows to be opened. On moderately heavy soils, particularly in a wet climate, it is often better to give also a cross-ploughing, as under such circumstances the surface becomes hard and compacted by the heavy winter rains, particularly if, as frequently happens, there is keen frost early in the winter and heavy rain during January, February, and March. The frost produces a fine surface tilth, which is afterwards washed together by the subsequent rains.

When a sufficient depth of loose, free soil has been obtained, and this usually is not difficult on typical potato soils, the rows are opened by a ridging plough, though occasionally an ordinary plough is employed instead. In cultivation on a large scale two or three furrows may be opened at once by one or other of the special implements available.

Special care in ensuring absolutely uniform width and straightness of the rows is necessary, if subsequent cultivation is to be carried out to the best advantage by labour-saving machinery. Where, for instance, cultivators or grubbers taking two or three rows at a time are used, any variation in the width of the rows makes it impossible to use the implement in the most effective manner. Even with grubbers and scufflers taking only one row at a time, unless the rows are all of exactly the same width, either the wider rows will not be cultivated as near the plants as they ought to be, or else the plants in narrower rows will be badly damaged.

### Cultivations for Potatoes after Grass.

Where it is desired to give potatoes the best possible chance it has long been the custom to take them after the temporary grass in the rotation, and reference has already been made to the fact that during the war the crop was found to be one of the most suitable for taking after old grass. The method of cultivation already described cannot, as a rule, be followed even after temporary grass, and is quite impossible after old grass, as the sod, if simply ploughed down in autumn, would interfere with the making of rows in the following spring. Various methods of getting over this difficulty are adopted. In the case of *temporary grass* one of the commonest is to give a comparatively shallow first ploughing, and then to break up the turf by means of harrows and cultivators. This is not difficult after one or two years' grass, and when the sod is sufficiently dis-

integrated a deep ploughing, using a skim coulter on the plough, buries the fragments of turf, which cause no trouble when the rows are subsequently made.

The great increase in the use of disc harrows and tractors in this country has brought into practice a more rapid method of securing the same object. The turf is cut up in the first place by disc harrowing two or three times in different directions with a sufficiently heavy harrow, and on comparatively light soils this is quite sufficient as a preliminary to the deep winter ploughing. Incidentally, it may be noted that the disc harrow is a particularly useful implement in preparing, for potatoes, soils containing decaying turf. Ordinary harrows and cultivators drag out the sods in large masses which often prove unmanageable; the disc harrow cuts up the sods without dragging them to the surface.

In the case of really *old pasture*, particularly where a dense, spongy sod exists, the methods described above are not particularly satisfactory, as, until a certain amount of rotting has taken place, the dry fibrous layer is very difficult to tear or cut up. In such cases one of the best plans is to give a double ploughing. A first plough, drawn by two horses, takes off the sod in as thin a layer as possible, and turns it to the bottom of the furrow, where it is covered by the second plough which follows in the same track, and is set to turn as deep a furrow as possible. This naturally requires considerable power, and three or four horses or a tractor are necessary. In this way the sod is completely covered by a layer of 6 or 8 in. of soil, and the subsequent operations in the preparation for potatoes do not touch it. It can be gradually broken up during the summer by deep grubbing, or subsoiling, between the rows, and by the following winter is sufficiently rotten to be brought to the surface, and thoroughly broken up in preparation for another crop. Naturally, such a method is only possible on particularly deep soils, such as the alluvial soils of the Fen district and other similar areas.

Another method, not so good in many ways as the foregoing, was adopted during the war on sandy loams in various parts of the country. The grass was ploughed to a depth of 4 or 5 in., and as the ploughing proceeded, potatoes were placed in every third furrow, just under the edge of the preceding furrow slice, so that they were not crushed by the horse walking in the furrow. After ploughing had been completed the land was well harrowed, so as to work down the soil as much as possible before the potatoes appeared at the surface. When the plants appeared above ground the rows were, of course, clearly marked, and scuffling and grubbing could be carried out, and finally the potatoes earthed up. This, although a somewhat rough and ready method, and only practicable where the grass had been fairly well and uniformly grazed, gave excellent results in many cases.

Similarly, potatoes were frequently grown by dibbling the seed in

after ploughing, and again the results were often surprisingly good.

**Lazy-bed System.**

In connection with the cultivation of potatoes after grass, reference may be made to the " lazy-bed system ", generally associated with boggy districts in Ireland, though sometimes employed in Great Britain. Under this system beds, from 4 to 6 ft. wide and 2 ft. apart, are marked out, and, after some earth from the intervening spaces has been thrown over them, the manure is applied and the potatoes planted. These are covered with more soil from the paths. When the shoots are about 6 in. high a further layer of earth is applied. Naturally, a trench of some depth is excavated in this way, and the existence of the trenches explains the survival of the system in the districts with which it is associated. They act as very efficient drains, and prevent the soil on which the potatoes are growing from becoming water-logged, as would frequently be the case if the crop was cultivated in such circumstances in the ordinary way.

**Manuring.**

As mentioned above, it may be considered desirable to apply part of the farmyard manure broadcast in the autumn or winter, but, nevertheless, the spring is the time at which the greater part of the potato crop is manured, and the whole question of manuring may be considered now.

Generally speaking, farmyard manure, or some other organic material such as seaweed or town manure, is regarded as almost essential for the crop, although, when taken after grassland, it is not uncommon for the crop to receive artificial manures alone. The quantity of farmyard manure applied varies very much, some growers giving very large dressings both with and without artificial manures, but, generally speaking, the most profitable practice will be found to lie in giving a moderate dressing of farmyard manure, supplemented by artificial manures rather than a very heavy dressing of farmyard manure alone. Many experiments have been carried out in all parts of the country, and the following results, which give the averages for a considerable number of experiments in North Wales, may be quoted as fairly typical, though it is perhaps necessary to mention that North Wales soils are naturally rather rich in organic matter, as a result of leaving grass down for at least three or four years during the rotation.

| Manuring per Acre. | Average Weight of Crop per Acre Tons. | Cwt. |
|---|---|---|
| No manure | 4 | 13 |
| 10 tons farmyard manure | 7 | 12 |
| 10 tons farmyard manure *plus* complete mixture of artificials | 9 | 5 |
| 20 tons farmyard manure | 8 | 16 |

Where large quantities of farmyard manure are available it is possible that a dressing of, say, 15 or 20 tons per acre may be applied with advantage, but in the great majority of cases the amount of farmyard manure available is not too great, and it is better to spread it over as large an area as possible, supplementing it with suitable artificials, than to apply heavy dressings to a small part of the farm and rely entirely on artificials for the rest.

As regards the nature and quantity of artificials that may usefully be employed, much depends on the character of the soil and its known response to different manures. Generally, a fairly complete mixture will be found best to supplement a moderate dressing (say 10 or 12 tons per acre) of farmyard manure. Nitrogen, phosphate, and potash are all likely to give a profitable response, and the experiments previously mentioned may be further quoted.

| Manuring per Acre. | Average Weight of Crop per Acre. Tons. | Cwt. |
|---|---|---|
| No manure | 4 | 13 |
| 10 tons farmyard manure | 7 | 12 |
| 10 tons farmyard manure; 101 lb. sulphate of ammonia; 262 lb. superphosphate; 82 lb. sulphate of potash | 9 | 5 |
| 10 tons farmyard manure; 262 lb. superphosphate; 82 lb. sulphate of potash; (*omitting sulphate of ammonia*) | 8 | 14 |
| 10 tons farmyard manure; 101 lb. sulphate of ammonia; 82 lb. sulphate of potash; (*omitting superphosphate*) | 8 | 14 |
| 10 tons farmyard manure; 101 lb. sulphate of ammonia; 262 lb. superphosphate; (*omitting sulphate of potash*) | 8 | 16 |

From the above it is seen that the omission of any one of the three manurial constituents reduced the weight of crop almost equally as compared with the complete mixture. These, however, are average results, and in individual cases, on different types of soil, the effects of the various manurial ingredients differed considerably.

The importance of potash for potatoes is often emphasized, and, generally speaking, it is specially needed on the lighter class of soils, but on some of the heavier loams its use may be somewhat restricted so long as a fair dressing of farmyard manure is applied. The influence of sulphate of potash is often beneficial to quality, apart from consideration of yield. Similarly, nitrogen can be profitably employed in fairly large quantities on exhausted soils, but if applied in large quantities to soils in good condition, may do more harm than good by increasing susceptibility to

disease. Phosphate is required in moderate quantities on practically all soils, but is not of such supreme importance as in the case of swedes and turnips.

The intensity of the artificial manuring in actual practice varies enormously, and, paradoxical though it may seem, the heaviest manuring is usually given on the best class of soil. Where it is known from experience that climate and the physical characters of the soil enable large crops to be grown, particularly perhaps in the eastern districts, very heavy dressings are frequently applied; for instance, the late Major Spence, in a paper read to the Farmers' Club, described his manuring system as follows:

"The whole of my potato break is dunged or covered with seaweed, and the greater portion of my break is land of one year's grass cut for hay, and the surface dunging applied immediately after the hay is cleared, so that, with the aftermath, I give the land a large quantity of humus. My usual mixture is 3 cwt. sulphate of ammonia, $\frac{1}{2}$ cwt. nitrate of potash—in some cases 1 cwt. of this—1 cwt. sulphate of potash, 1 cwt. muriate of potash, 3 cwt. pure dissolved bones, 3 cwt. superphosphate."

Similarly in the growth of early potatoes it is customary to give large quantities of artificial manure in order to induce the most rapid growth possible, so as to make it possible to lift the crop early, and thus command the highest prices. In general, however, it will be found that under average conditions, for supplementing a moderate dressing of good farmyard manure, quantities of artificial manures supplying per acre about 20 lb. nitrogen (N), 100 lb. phosphate [$Ca_3(PO_4)_2$], and 50 lb. potash ($K_2O$) will give the most profitable results.

Nitrogen is as a rule best applied in the form of sulphate of ammonia, phosphate in the form of superphosphate, and potash in the form of sulphate of potash, and the quantities mentioned correspond roughly to 1 cwt. sulphate of ammonia, 3 cwt. superphosphate, and 1 cwt. sulphate of potash. Nitrate of soda may be given as a top dressing if required, particularly in the case of crops in which growth has been checked, for instance, by late frosts. Some growers continue to use more slowly acting organic manures, such as rape meal, fish guano, &c., but as a rule these are more costly per unit of nitrogen than sulphate of ammonia, and are not so rapid or efficient in their action.

As regards potash, there is a general belief that the use of such manures as kainit and muriate of potash, which contain chloride, affect the cooking quality of the tubers. Most growers, therefore, prefer to use sulphate of potash. The fact that some of the finest quality potatoes are grown on land of coastal districts, which probably receives a greater amount of chloride from sea-spray and dressings of seaweed than is contained in customary applications of these manures, is worthy of investigation.

In compounding the mixture of artificial manures, care should be taken that the manures so mixed will not chemically interact to produce loss of any constituent. If the mixture is not to be sown immediately, a drying agent, such as steamed bone flour, should be used.

The manure is sown by hand or machine in the drills which have previously been opened after the land has been reduced to the desired tilth, on the top of the farmyard manure if it is being applied at this stage. If the latter has previously been ploughed in, the use of the combined double driller and manure sower is a saving of time and labour.

## Manuring with Artificials only.

The foregoing recommendations apply to cases where artificials are required to supplement a fair dressing of farmyard manure. In cases where farmyard manure is not available, the quantities suggested should be at least doubled, and in this case there is something to be said for giving a greater variety, so as to ensure a steady supply of food for the plant right through the season. For instance, part of the nitrogen and phosphate might be usefully given in the form of fish meal or guano, or a mixture of rape cake and steamed bone flour. Where farmyard manure is not applied it is likely to be specially necessary to give ample supplies of potash, and where it is desired to use kainit, or a similar potash manure containing chloride, the safest plan would be to apply this to the land a month or two before the crop is to be planted. In this way the chloride would be washed out of the soil, and the potash retained in a harmless form. Except on peaty soils manuring with artificials alone, as a rule, is only practised in cases where potatoes follow temporary or permanent grass. The grass leaves behind a large quantity of decaying organic matter, which to a great extent takes the place of farmyard manure. With a well balanced mixture of artificials, however, large crops of excellent quality can be produced.

## Time of Planting.

The time of planting potatoes varies very much according to local conditions, seasons, and the importance which potatoes occupy in the general farming system. Taking the country as a whole, the planting season may be said to extend from the beginning of February to the end of May, the former applying particularly to the somewhat limited early potato growing districts, the latter to main crop varieties in late districts and backward seasons. April is the most important planting month, by far the greatest area of potatoes being planted then.

If the seed is stored only in clamps or pits, the young shoots or sprouts grow very rapidly as soon as warm weather sets in. It is important to plant before these have made much growth, otherwise they are knocked off in planting, with the result that there is much waste of the most valu-

able part of the potato, and instead of a few sturdy shoots a large number of more weakly growths are produced. Where seed is stored in boxes, as described below, there is not the same necessity for early planting, as the first growth is preserved, and the crop ultimately obtained may be just as good if planted in May as if planted at the beginning of April.

**Treatment of Seed.**

In comparatively cool districts, where little growth is likely to take place before the ordinary time for planting, seed of late varieties may be stored quite well in ordinary clamps or " pits ", and planted direct from them at the end of March or beginning of April, but where early potatoes are grown, or where the planting season is likely to be late, it pays well to store the seed potatoes in shallow trays or sprouting boxes, an illustration of which is given.

It will be noticed that these boxes are so designed that they can be placed in tiers one above another to any height, and if properly arranged in rows in a well lighted building, the potatoes in each box receive a fair amount of light. This results in sturdy, green shoots, instead of the long weak shoots produced when the potatoes are stored in the dark. Furthermore, the boxes are so designed that they can be taken to the field and planting done direct from them. In this way the shoots are preserved intact, and in the case of a late season the increase in crop as compared with seed stored in clamps has frequently been shown by careful trials to amount to 2 or 3 tons per acre.

Where early potatoes are grown, boxing of the seed is essential, and it is a highly profitable system even for late varieties in districts where growth in the clamps is generally early and rather rapid, as, for instance, in many districts in England. Even in cooler districts, where most of the planting can usually be done before there has been much growth in the clamps, it is desirable to box at least part of the main crop as a kind of insurance against a season in which for various reasons it may be impossible to complete planting sufficiently early. The initial cost of boxes, though fairly high, is often recovered by the increase in crop in the very first season. Using the smaller type of box illustrated, which holds about 18 lb. of potatoes, at least one hundred will be required per acre, and at the present time the cost of boxes is about 9*d.* each. In addition, on many farms there are not suitable buildings for housing the boxes, and it is necessary to erect special sheds for the purpose, but it must be remembered that these are capital expenditures which do not recur annually, as the boxes themselves, with ordinary care, will last a good many years, and probably 10 or 15 per cent depreciation represents the annual cost.

On many of the potato-growing farms in the Fen district, where boxing is carried out on a large scale, special glasshouses are erected for sprouting

SPROUTING BOXES: LARGE AND SMALL SIZE

*Facing p. 32, Vol. II*

the potatoes, but under other conditions, where the large initial outlay would hardly be justified, any airy, well lit building would answer the purpose.

The seed may, if desired, be placed in the boxes as soon as the potatoes are lifted, and where comparatively small lots are dealt with this is the best plan, but the benefit is almost as great if the potatoes are boxed during the winter, provided that the seed has not started to sprout before it is placed in the boxes. On a small scale, as, for instance, in garden practice, the tubers may be arranged with the rose end uppermost, but this is only possible on a small scale, and does not really make very much difference.

In addition to the main advantage, which is the securing of a heavier crop, the system of sprouting potatoes in boxes, as described, has the advantage of enabling seed to be examined during winter, and diseased tubers being removed in bad weather, when it would be impossible for work to be performed out of doors. In this way losses caused by rotting in the clamp, which are often serious, are avoided. After the sprouts begin to show, rogues can also, as a rule, be readily detected and removed. In this way the variety can be kept very much purer.

### Selection of Seed.

*Size of Seed.*—Various points regarding the selection of seed—as, for instance, sources of seed, freedom from disease—will be dealt with under separate headings, but leaving for the moment these special considerations it may be said that selection of seed is generally a question of grading according to size.

Normally, tubers which will pass through a $1\frac{1}{4}$-in. mesh riddle are described as "chats", and are mainly employed for pig and cattle feeding. Large potatoes, which will not pass through a riddle of about $1\frac{3}{4}$-in. mesh, are described as "ware" or marketable potatoes. The intermediate grade, which pass through a $1\frac{3}{4}$-in. mesh, and remain on a $1\frac{1}{4}$-in. mesh, are the potatoes most commonly used for seed. The upper limit of size, however, varies considerably. In the case of a variety available only in limited quantity the crop may be sold for seed "as grown"—that is, the whole crop, large and small, is included. In the case of varieties available in rather larger quantities, the seed may be dressed through a 2- or a $2\frac{1}{4}$-in. riddle, the lower limit almost invariably being a $1\frac{1}{4}$-in. riddle.

A grower, in buying seed, prefers as a rule to buy the smaller seed, as a given weight of small seed will plant a larger area than the same weight of large seed, and the labour of cutting is obviated. So long as the small seed is obtained from a healthy crop, and represents tubers which have not fully developed, the plan is satisfactory; but it is necessary to keep in mind the possibility that the small tubers may represent, not the undeveloped produce of healthy plants, but the fully grown tubers of

weakly or diseased plants. If this is the case the selection of small seed year after year results in an increasing proportion of tubers which can only produce unsatisfactory plants. Growers in the south, who have to change the seed every year or at most every two years, can hardly be expected to do much in the way of seed selection, but growers of seed in districts where deterioration is very slow, and who are able to maintain the same stock year after year, would be well advised to select their seed stocks by planting only the produce of strong, vigorous plants, which have produced a large number of good-sized shapely tubers. This involves lifting by hand and a considerable amount of additional labour, but in the long run a handsome return would be secured.

At the present time many growers, who specialize in the production of seed, plant chats very thickly in narrow rows in order to secure the largest quantity possible of seed-size tubers.

### Maturity of Seed.

Experiments carried out in many districts have proved fairly conclusively that better crops are likely to be obtained from comparatively unripened potatoes than from those which have been allowed to ripen off naturally.[1] In the ordinary way potatoes from which seed is selected are lifted from, say, the middle of September to the end of October, according to their time of reaching maturity, but by lifting about a month before the usual time—that is, while the tops are still green—the immature seed thus obtained will, in most cases, produce healthier and heavier crops than that of fully ripened seed. It is, however, necessary to take special precautions in the storing of immature tubers lifted in this way. At this stage the skin is very thin and easily rubbed off, the weather in most seasons is comparatively warm, and if the potatoes were stored in clamps in the ordinary way much rotting would take place. The best plan is to place the tubers immediately after lifting in sprouting boxes. Where this cannot be done they should be allowed to remain on the ground for a day or two to allow the skin to become hardened, after which they may be spread out thinly in a cool dry shed. Recent investigations on leaf curl and similar diseases suggest the possibility that an important reason for the superiority of immature seed may be the reduced liability of infection with the various virus diseases.

### Cut Seed.

With normal seed-size potatoes, dressed through $1\frac{3}{4}$-in. riddle and over $1\frac{1}{4}$-in. riddle, not more than 15 cwt. will be required to plant an acre in 27-in. rows, but with seed dressed through a $2\frac{1}{4}$-in. riddle as much as 30 cwt. per acre might be required, and as good seed is often

[1] See *Journal of the Ministry of Agriculture and Fisheries*, Vol. XXIII, No. 6 (September, 1916).

expensive, recourse must be had to cutting. With most varieties of potatoes cut seed gives quite satisfactory results, but with some kinds very unsatisfactory crops are produced if cutting is practised. A notable case is that of the variety Majestic, the tubers of which are very large. When this variety was introduced many growers had partial or total crop failures simply because they cut practically all the seed.

In cutting potatoes care must be taken to leave a sufficient number of eyes or sprouts on each set, and in the case of a long or kidney-shaped potato this usually involves cutting along the length of the potato, *not* across it. Except in the case of special varieties such as those referred to above, cut seed, if properly treated, will generally give as heavy a return as whole seed of the usual size. The best plan, where cut seed is to be used, is to plant immediately after cutting, but where a large amount has to be dealt with it is usually necessary to do the cutting some time previously in order to avoid delay in the planting. In such cases it is advisable to dust the cut surfaces of the tubers with ground quicklime, and then to spread the seed out thinly either on a floor or in sprouting boxes in order to avoid heating.

In special cases a method which was tried with Majestic in 1919 at the experimental farm of the University College of North Wales, Bangor, may be recommended. Instead of completely dividing the tubers, the knife was not taken quite through, and the two halves remained attached by a small strip of skin and flesh along the back. The results of the whole experiment are shown in the following table, and indicate the amount of loss which may result with certain varieties if special precautions are not taken.

| Plot. | Treatment. | Number of Plants on 31st July in 80 yd. of row (average of two series). |
|---|---|---|
| 1 | Cut and limed, 5th May; planted, 20th May. | 109 |
| 2 | Cut (not limed), 5th May; planted, 20th May. | 53 |
| 3 | Half cut, 5th May; finally divided and planted, 20th May. | 142 |
| 4 | Uncut; planted, 20th May. | 167 |
| 5 | Cut and limed, 20th May; planted at once. | 134 |
| 6 | Cut (not limed), 20th May; planted at once. | 129 |

## Change of Seed.

It has long been known that, in the cultivation of potatoes in a lowland southern district, it is most desirable to obtain from time to time seed

grown in a northerly, cooler, and later district. The following results, selected from a large number of published reports on experiments carried out in different parts of England and Wales, illustrate the benefit obtained by securing Scottish seed as compared with home-grown seed. In many cases seed from the North of Ireland has given as good results as Scottish seed. In Scotland farmers in the lowlands find it beneficial to obtain seed from farther north, or from a more elevated and more backward farm.

### North Wales

Average results on Fourteen Farms in 1908

| Seed. | Average Weights at Fourteen Centres. | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Marketable. | | | Small. | | | Diseased. | | | Total. | | |
| | Tons. | Cwt. | Lb. | Tons | Cwt. | Lb. | Tons. | Cwt. | Lb. | Tons. | Cwt. | Lb |
| New seed (Scottish) | 10 | 16 | 35 | 1 | 12 | 81 | 0 | 11 | 72 | 13 | 0 | 76 |
| Once-grown seed | 9 | 0 | 44 | 1 | 2 | 111 | 0 | 17 | 96 | 11 | 1 | 27 |
| Twice-grown seed | 7 | 13 | 5 | 1 | 4 | 25 | 0 | 16 | 28 | 9 | 13 | 58 |

Average results on Fifteen Farms in 1909

| Seed. | Average Weights at Fifteen Centres. | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Marketable. | | | Small. | | | Diseased. | | | Total. | | |
| | Tons | Cwt | Lb. | Tons. | Cwt. | Lb. | Tons. | Cwt. | Lb. | Tons. | Cwt. | Lb. |
| New seed .. | 12 | 15 | 5 | 0 | 18 | 15 | 0 | 16 | 27 | 14 | 9 | 47 |
| Old seed .. | 10 | 17 | 35 | 0 | 19 | 69 | 0 | 18 | 37 | 12 | 15 | 29 |

### Essex, 1914

| Seed. | Yield per Acre. | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ware. | | | Seed. | | | Chats. | | | Total. | | |
| | Tons. | Cwt. | Lb | Tons | Cwt. | Lb. | Tons. | Cwt. | Lb. | Tons. | Cwt. | Lb |
| New seed (Scottish) | 7 | 18 | 2 | 3 | 11 | 0 | 0 | 15 | 1 | 12 | 4 | 3 |
| Home-grown seed | 5 | 3 | 1 | 1 | 11 | 2 | 0 | 9 | 0 | 7 | 3 | 3 |

CAMBRIDGE, 1905

| Variety. | History of Seed. | Total Crop. Tons. | Total Crop. Cwt. | Increase due to Change. Tons. | Increase due to Change. Cwt. |
|---|---|---|---|---|---|
| Up-to-date. | Five years in Cambridge. | 4 | 17 | 9 | 16 |
| | Fresh from Cromarty. | 14 | 13 | | |
| British Queen. | Three years in Cambridge. | 5 | 3 | 10 | 10 |
| | Fresh from the Lothians. | 15 | 13 | | |
| Northern Star. | Three years in East Anglia. | 4 | 15 | 12 | 18 |
| | Fresh from the Lothians. | 17 | 13 | | |
| Factor. | Three years in Cambridge. | 10 | 10 | 4 | 18 |
| | Fresh from the Lothians. | 15 | 8 | | |
| Factor. | Grown in Cromarty, 1904, from Cambridge seed. | 11 | 12 | 2 | 6 |
| | Grown in Norfolk, 1904, from Cambridge seed. | 9 | 6 | | |

Various theories have been suggested to explain the effect of change of seed, the one most commonly held being that the potatoes grown in the districts from which the most productive seed is obtained are comparatively immature when lifted, and thus the benefits from using immature seed, as previously indicated, are secured. This theory, however, could only account for part of the effect, which is probably due to a combination of a number of causes, of which the immaturity of the seed may be one. Another contributing factor is doubtless the fact that sprouting in the clamps in spring is not nearly so advanced in later districts as in the south, and thus, by securing seed from Scotland a southern grower obtains in some measure the same kind of benefit as he would obtain by boxing his seed. This view is, to some extent, supported by the fact that the effect of change of seed with early varieties, which are usually sprouted in boxes before planting, is not usually so great as with later kinds. Here, again, other factors may be partly responsible, since the early kinds are usually lifted before arriving at maturity, and also early in the season before aphis attack is common.

Recently the view has been advanced that the degeneration of potatoes in southern districts is due largely to the development of the so-called virus diseases, including "leaf curl" and "mosaic". These are spread very largely by aphides and certain leaf-biting insects, which are more likely to abound in a hot, southern climate than in a cool northern district. It is perhaps premature to regard the matter as definitely proved, but there can be no doubt that in many cases this theory accounts for phenomena which were previously inexplicable. Incidentally, it is interesting to note that degeneration of potatoes due to virus diseases is by no means a modern

phenomenon, and was mentioned in most of the early writings on the cultivation of potatoes.

At the present time the benefit obtained by obtaining new seed is fully recognized by all the large growers of potatoes in southern and lowland districts. The usual practice is to obtain fresh seed every year for a small proportion of the total area to be planted. The crop from this, called once-grown seed, is used in the following year to plant the bulk of the area. In some cases the once-grown seed is found to give results almost as good as the fresh seed, particularly where it is sprouted before planting; in any case the expense of procuring the fresh seed makes the farmer unwilling to obtain new seed for the full area every season, though in the *Journal of the Ministry of Agriculture*, April, 1921, Mr. R. H. Currie states that, in the South-eastern and Home Counties Scots-grown seed practically always gives far heavier yields than once-grown seed.

Those who support the virus disease theory of degeneracy contend that the practice of buying a small proportion of new seed every year is unsound. The crop from the new seed planted alongside old seed becomes infected in the first season with whatever virus diseases prevail in the area, and the crop from this seed in the following year is consequently not so good.

If this theory is proved to be correct, it seems probable that methods for the prevention of aphis attacks will soon be established, and the heavy expense incurred in securing seed from a northern district will no longer be necessary.

### Methods of Planting.

In spite of the introduction of potato-planting machines, by far the greater part of the potato area in Great Britain is still planted by hand. Machines, however, are being gradually perfected and are used in some districts, particularly in Scotland.

Provided that the seed is of a fairly uniform size and moderately round, potato-planting machines perform very good work, and even with a small staff of workers a large acreage can soon be overtaken. Occasionally two tubers will be turned out together and a few may be missed, but the man in charge of the machine and walking behind it can fairly easily remedy such mistakes. If the seed, however, is varied in size and particularly if it is of a long or kidney shape, such a machine cannot be used at all successfully, while it is obviously unsuited for the planting of cut seed and sprouted seed. Machines for planting sprouted seed are receiving attention and have been placed on the market. They appear to be satisfactory under special conditions, though they have not come into general use.

The actual cost of planting is not a particularly serious item, and the saving effected by the use of a machine is not very great, but in districts

where labour is scarce, machines enable a large acreage to be planted in a short time, and this is often all-important.

In planting a field the labour should, if possible, be so arranged that opening the rows, manuring, planting, and closing the drills proceed simultaneously at a uniform rate. From $\frac{1}{2}$ to 1 ac. is a fair day's work for a planter putting down unboxed seed; when sprouted seed is planted from boxes considerably less than this would be done. The most expeditious plan with unboxed seed is to have a large apron (usually made from an old sack) with one end fastened round the waist and the other end suspended at a suitable length by an attached cord passing round the neck. In this way a sort of large pocket, hanging in front of the planter just below the waist, is formed; it is open at both sides, and planting can be done with both hands. A cart loaded with seed travels up the field by the side of the planting gang, and the supply of each planter is replenished from this as required.

If planting is done from boxes, only one hand is free for dealing with the seed, and, naturally, progress is slower, apart from the fact that greater care has to be taken in handling sprouted tubers.

Almost invariably the seed is planted in the rows on top of the farmyard and artificial manure, and covering is done by splitting the ridges. In order to avoid crushing the tubers, or kicking them out of position, the horse, which would naturally walk in the uncovered row, is made to walk on top of the next ridge.

Occasionally, however, in Lancashire and other areas, potatoes are not planted in this way. There the ground is cultivated, manured, and the ridges split early in the season before planting commences. The sprouted seed is then planted in the ridges by a process similar to dibbling, but a spade is used instead of a dibble. The cost of planting in this way is greater, but the plan enables the preparation of the ground to be completed earlier, at a comparatively slack season. Naturally the system is only suited to sandy soils, which can be cultivated during the winter months. Reference has already been made to the lazy-bed and other methods of planting suited to special circumstances, particularly where the crop is taken after old grass.

### Width of Rows and Distance between Sets.

The width of the rows varies according to the amount of growth expected of the foliage, and so long as there is room for full development of the tops, and for the formation of a good ridge which will enable the tubers to develop without exposure to light, the narrower the rows the heavier will the crop be. As a rule early varieties are planted in rows 24 or 26 in. wide, maincrops 27 to 29 in. wide.

In deciding the width of rows consideration must also be given to the state of the land at planting time. If the soil is in a rough, rather foul

state and likely to require an exceptional amount of cultivation, wider rows should be made so as to allow of the passage of implements and horses, up to a comparatively late stage, without damage to the crop.

Similarly the distance apart at which the tubers are placed in the rows varies a good deal, but for most maincrop varieties 12 to 15 in. is about the best distance, and in the case of early varieties 9 to 12 in. Reference has already been made to the custom of planting small potatoes very thickly in the rows where a crop of seed-size potatoes, rather than large tubers, is required.

If, as is the case in some districts with earlies and second earlies, a crop of cabbages, broccoli, &c., is to be planted between the potato rows after the final earthing, wider rows must be made than would be necessary otherwise. In this system the potatoes are lifted by fork as soon as possible, and the intercrop, which must not be damaged during the process, has possession of the ground during late summer and autumn.

### Cultivation Subsequent to Planting.

The great advantage of potatoes over roots as a cleaning crop is the fact that a considerable amount of cleaning can be done cheaply by horse labour after planting; not only so, but the more the land is worked the better it is for the crop. The operations are designed to secure the greatest possible depth of loose mould, and at the same time to kill all weeds and thoroughly clean the land.

The process should commence almost as soon as planting has been completed, the first operation being to harrow down the rows either with a special saddle-back harrow or a chain harrow. This operation, if done when the soil is in a suitable condition, " neither wet nor dry ", will break down any clods left by the plough on the top of the ridge, and at the same time destroy any weed seedlings which may be appearing. If the land is infested with Couch, it will shake the stems of the Couch free from soil, and a short exposure to hot sun and drying winds will destroy a great proportion of this troublesome weed. After the harrowing, a scuffling or light grubbing of the rows may be given, or the ridges may be made up again at once with a ridging plough.

These operations will have left the tops of the ridges in a loose, friable condition favourable for the germination of weed seeds, and also favourable to the steady emergence of the growing potato shoots. Just before they reach the surface, however, a second harrowing of the ridges should be given, care being taken to time the operation so that no great damage is done to the young shoots by the harrows. The crop is then hoed by hand to destroy any weeds not affected by the previous operations, and a heavy grubbing between the rows to loosen the soil as deeply as possible follows. The drills are then lightly earthed up. The drill grubber universally employed in Scotland, but not so often seen south of the Border,

is an invaluable implement in securing a great depth of loose mould. With land at all foul with Couch, or in rough condition at planting time, an intermediate series of operations of the same kind should have been performed, and in any case, if time and other work of the farm allow of its being done, the extra cultivation usually results in a substantial increase of crop.

If these operations have been carried out properly, very little further cleaning of the land will be required, as the rapidly growing crop will soon smother out any weed seedlings which may appear. Further operations are designed mainly to secure a massive well set up ridge, which will hold the crop and leave no tubers exposed to the light. Where the soil is hard, a subsoiling plough may be used instead of the grubber to get the desired depth. The final earthing up in the case of maincrop varieties usually takes place sometime in July, according to the earliness of the district and the state of the crop. It should be left as long as possible, but not delayed until growth has taken place to such an extent that serious damage to the foliage is inevitable when horse implements are taken through the crop. The final earthing up should be as deep as practicable in order to prevent exposure of tubers and to reduce liability to disease.

**Spraying of Potatoes.**

Spraying, where practised, is done with the intention of warding off attacks of blight (*Phytophthora infestans*), but is by no means universally carried out. The material employed is either Bordeaux mixture or Burgundy mixture, the usual quantities per acre being as follows:

*Bordeaux Mixture*: 20 lb. copper sulphate (of at least 98 per cent purity); 10 lb. quicklime (freshly burnt); 100 gall. water.

*Burgundy Mixture*: 20 lb. copper sulphate; 25 lb. washing soda; 100 gall. water.

Two sprayings are given where possible, the first about the middle of July, before the flower buds burst into bloom, and the second, two or three weeks later, care being taken to time the operations so that the damage done to the foliage in going through the crop at the last spraying is not excessive.

Opinions differ greatly as to the benefits to be derived from spraying, and in all probability local conditions determine whether it is beneficial or not. In the moist warm climate of Ireland, where blight is nearly always a serious scourge, spraying is commonly done almost as a matter of course. In North Wales, where conditions are somewhat similar, the average results of experiments conducted in the fifteen years 1901 to 1915 at ninety-one farms were as follows:

| | Average Weights of Potatoes per Acre. | | | | | |
|---|---|---|---|---|---|---|
| | Marketable. | | Small. | Diseased. | Total. | |
| | Tons. | Cwt. | Cwt. | Cwt. | Tons. | Cwt. |
| Sprayed. | 10 | 6 | 18 | 11 | 11 | 15 |
| Unsprayed. | 8 | 12 | 21 | 15 | 10 | 8 |

In other parts of Great Britain the results of spraying experiments have been somewhat varied, and actually spraying is not extensively practised, except in the Fen district. Even there experiments conducted by the Ministry of Agriculture in 1919 suggest that the operation may often result in no gain.

The North Wales results summarized above show clearly the effect of spraying in districts where it is attended with beneficial results. The proportion of diseased tubers is less on the sprayed than on the unsprayed plot, but the most striking effect is shown by a comparison of the weights of marketable potatoes. Spraying prolongs the growth of the plant, and results in a greater crop of marketable potatoes. The prolongation of the growing period may in some cases be altogether undesirable. With late varieties in a district subject to early autumn frosts delay in maturing may result in a frosted crop and serious loss.

The labour and trouble involved in spraying are considerable, and unless the mixture is carefully prepared serious scorching of the leaves may be caused. As a means of reducing the trouble and labour of application, systems of *dry spraying* have been evolved, and are extensively practised in the eastern counties. The spraying material ready mixed is obtained in the form of a very fine powder, and applied with special machines during the night or early in the morning when the leaves are moist with dew, or in showery dull weather. The results do not appear to be quite so satisfactory as with the wet sprays, but the application is very much cheaper and less troublesome, while the difficulty sometimes experienced of obtaining water in large quantities does not arise.

Where spraying with Bordeaux or Burgundy mixtures is practised, the following is usually the method adopted. The copper sulphate for an acre (20 lb.) is dissolved in, say, 50 gall. of clean water in a large wooden tub. This is easily done if finely powdered material is used. In another tub the lime or washing soda for the same area is dissolved separately. When both are ready the lime or soda solution is slowly poured into the copper sulphate solution and well stirred. The mixture should then be tested with blue litmus paper. If the paper turns red, more lime or soda solution should be added until the litmus paper remains blue. If the steel blade of a knife be dipped into the solution no copper deposit

should adhere to it. The bulk mixture is then made up to 100 gall. with clean water, and poured through a fine cloth or piece of gauze into the barrel of the spraying machine.

It is essential that the mixture should be applied soon after it is made, as, if allowed to stand for more than an hour or two, chemical changes take place which will result in the "scorching" of the leaves when the crop is sprayed. The same result follows if the mixture is not made neutral as tested by the litmus paper (see p. 243).

## Harvesting.

In the case of early varieties lifting may take place in the end of May, in June, or in July, though the majority, excluding the Channel Islands potatoes, are lifted from the end of June onwards (see The Early Potato Crop).

Second early and late varieties are nearly always allowed to remain until mature, this stage being indicated by the dying down of the top or haulm and the hardening of the skins of the tubers. Once this stage has been reached the sooner the crop is lifted the better, as, if left in the ground, the tubers are exposed to the risk of infection by blight. Most of the second earlies should be lifted in September, and the majority of the maincrop varieties ought to be safely stored by the end of October, before the advent of much frost.

The actual lifting may be done in different ways, but the following three methods are the most important for large-scale cultivation:

(*a*) *Digging by Hand.*—This method, although it has been largely superseded by the potato digger, is still followed in many districts where Irish or other labour is accustomed to take the digging on a piece-work system. In Lancashire and Cheshire, where the system is largely practised, men work in pairs, digging adjacent rows, one man working left-handed, the other right-handed. The diggers pick up and roughly sort the potatoes as they proceed, the ware being thrown into one hamper, the chats and diseased into another. The hampers employed are square or oblong baskets, each holding about a hundredweight; and the full hampers, which are left in rows as the work proceeds, are afterwards loaded on to lorries or into carts. In pre-war times, when sufficient Irish labour was available, the cost of lifting in this way did not greatly exceed the cost of lifting by digger, and had the important advantage in a western district of enabling lifting to proceed when the weather and state of the soil would have made it difficult to use a digger. The present scarcity of the right type of labour has, however, tended to reduce the area of potatoes lifted in this way. Where an intercrop of any kind is grown, digging by hand is, of course, the only practicable method.

(*b*) *Lifting by Plough.*—A ridging plough, which may be fitted with bars instead of the ordinary mould boards, is used to split the ridges,

and is set at such a depth as to work below the tubers. Alternate ridges are split in this way, and pickers follow. Only a small proportion of the tubers are absolutely exposed in this way, and the pickers must run their hands through the soil in order to get the whole crop. When alternate rows across a portion of the field have been lifted in this way the remaining rows are then dealt with, and finally a good harrowing and cultivating is given in order to expose any potatoes which had been missed in the first gathering. This method has the advantage of lifting the crop with a minimum of damage, but this is more than counteracted by the greater difficulty of getting up all the tubers. Where, however, the area of potatoes grown is too small to make it worth while to buy a special potato digger, this method is as good as any.

(*c*) *Lifting by Potato Digger.*—The use of potato-digging machines has been common in potato-growing districts for many years, but the number employed has been greatly increased during the last few years as a result of labour shortage during the war.

There are several types but the principle is much the same in all cases. A broad share is set to cut through the ridge, just below the level of the tubers. Immediately behind the share is a set of revolving forks, which throw the soil and the tubers to one side. In one type the potatoes are thrown straight out. In another case the forks have a slower lifting action. If the machine is properly adjusted, the tubers are left on the surface in a fairly compact row, and can be gathered with comparatively little trouble. The chief point to be attended to is the depth at which the share is set to work. If too shallow, some of the tubers will be cut; if too deep, soil is thrown on to the top of the potatoes.

The use of the potato digger has greatly relieved the work of harvesting the crop, particularly as women and quite unskilled labour can be utilized to a large extent for the actual picking.

In order to keep a digger continually at work along both sides of a strip, a gang of about two dozen women or boys is required for the picking. They should be provided with an ample supply of baskets, which are left as they are filled, to be emptied into carts.

As the harvesting of the potatoes is the heaviest and most anxious part of the whole year's work on the crop, it may be well to set out in detail the organization required to deal with it. One man and three horses will be required for the digger; twenty-four pickers, with a foreman to see that each keeps to his or her right length, and to ensure that picking is as clean as possible; two men with carts carting the crop to the clamp, the site for which should have been prepared previously. If large hampers are used instead of small baskets, an additional man will be required to help to empty the hampers into the carts. One or two men will be required at the clamp to shape the heap, put on straw, and do a certain amount of earthing up. A force of this kind ought to lift 3 ac. of a good crop in a

working day of about 8 hr., and just before the end of the day the ground dug should be harrowed, and the whole gang of pickers made to collect any potatoes left behind. If a sufficiently large gang cannot be got together, twelve women or boys will be able to gather the potatoes after a digger working in one direction only, and in this case two horses will be sufficient to draw the machine.

If a part of the crop can be marketed immediately after lifting, it is usually advisable to dispose of it then, even if a comparatively low price has to be accepted. The expenses and risk of storage are avoided, the cost of marketing is comparatively small, and the weight per acre actually sold will be much greater than if the crop has to be stored for even a month or two. No matter how clean and dry the crop may appear to be when lifted, the loss of moisture and attached soil, after even a short period of storage, reduces the weight of crop considerably. Incidentally, it may be noted that this loss accounts for the great discrepancy often found between the estimates of crops based on the weighing of a small area at lifting time, and the weight of crop actually sold during the winter.

**Yield.**

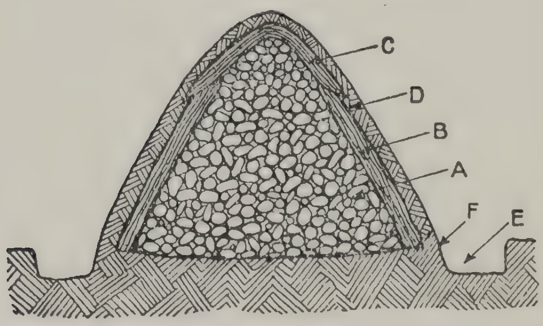
An average of 8 tons of ware per acre for the whole farm represents a good crop, assuming that the potatoes are sold in the ordinary way at intervals right through the winter and up to April or May, but under very favourable conditions this amount may be exceeded. The weight actually lifted in the autumn may be as much as 12 or 14 tons per acre, but, as pointed out above, this always includes a certain amount of moisture and attached soil. The sale of potatoes straight from the field is, however, the exception rather than the rule, so far at least as maincrop varieties are concerned. Apart from the fact that the market in autumn is usually glutted with potatoes, the necessity of getting the whole crop stored and safe from the risks of frost often makes it impossible for the sorting and marketing of even a part of the crop to be undertaken. The total crop raised consists of saleable or "ware" potatoes, seed, and chats. Under ordinary circumstances the proportion of these will be somewhat as follows: of the total crop, ware = 70 to 80 per cent, seed size = 15 to 20 per cent, chats = 5 to 10 per cent.

**Storage.**

The method almost universally adopted is to place the tubers in long heaps, known variously as clamps, pits (Scotland), pies (Yorkshire), hogs (Cheshire) in different parts of the country. These are given a cover first of straw and then of earth, and simple though the making of such a clamp may appear to be, it deserves more consideration than it sometimes receives. If the ground is sandy and well drained, a considerable saving of labour may be effected by sinking the clamp a little below ground-level, and this

doubtless accounts for the Scottish name of pit. The ground along the line of the clamp is loosened by means of a plough to the required length and width, and from this the soil is thrown out by hand to the sides, where it is handy for the subsequent covering of the heap. As the crop is brought in by carts, they are backed endways to the side of the pit and the load tipped in. Very little additional labour is required to give a well-shaped heap.

In wet districts, or on wet soils, such a plan is impossible, as the base of the heap would become water-logged during winter, and in such a case the clamp must be made above ground-level, the trench being excavated afterwards along each side to provide soil for covering the clamp, and to carry off water. The clamp can, of course, be made any length, but the width is a matter of some importance. If made too wide there is risk of heating and serious loss. A suitable width is about 4 ft. or 4 ft. 6 in., and the slope of the sides should be sufficient to throw off all the rain and melting snow likely to fall during the time of storage. With a perfectly sound dry crop this width may be exceeded, but if a proportion of the crop is diseased, or if it has to be lifted in bad, wet conditions, it is safer to reduce even this width. (In the west of Scotland 3 ft. is found to be wide enough.)



Potato Clamp

A, Potatoes; B, straw, side layer; C, straw, ridge layer; D, overlapping of ridge and side layer; E, trench; F, base of clamp.

As a further insurance against loss in the clamp, particularly if there is a substantial proportion of diseased tubers in the crop, ground quick-lime may be dusted among the tubers as they are put into the clamp. As a protection against certain rots which develop during storage, a small quantity of sulphur is sometimes dusted in along with the lime, but it must be confessed that, as a rule, the pressure of work at lifting time is so great that precautions of this kind, though admitted to be of value, are not often taken.

In wet districts, where it is difficult to get the crop lifted in dry, clean condition, the potatoes are often first put into small temporary clamps very roughly covered, and after the crop has all been lifted, these are roughly picked over, and the potatoes put into larger and more permanent heaps. The tubers will be found to have dried a good deal in the meantime, and are usually in fair condition for storing after the preliminary sorting.

As already indicated the first cover given to the clamp consists of straw, and for this purpose clean wheat or rye straw is much the best.

Labour can be reduced and a better job made if the straw has been tied in bundles as it left the threshing machine. In this way bundles can be placed along each side to a depth of about 6 in., the length of the bundle usually corresponding almost exactly to the height of the sloping side. Another length of straw placed on top of the ridge, with the ends bent down the two sides, completes the strawing, and a few spadefuls of soil fix the straw in position, until the harvesting of the whole crop has been completed. It is sometimes overlooked that the straw affords the main protection to the tubers; the subsequent covering of soil merely throws off the rain and keeps the straw in position. It is therefore a mistake to skimp the allowance of straw and to try to make up for it by giving an extra covering of soil. It is also most important that the ridge of the clamp shall remain uncovered with soil for about a fortnight, in order to allow of the escape of moisture and warm air. If the clamp is completely closed up at once, heating and subsequent loss is likely to occur. In order to keep the top free, a plank may be laid on top of the straw at the ridge as the soil is put on the sides, the space that is left being covered with soil at a later date when all risk of heating is over. In some districts drain pipes filled with straw are inserted in the ridge at frequent intervals as a means of ventilation, and are left all winter.

In a cold exposed district it may be found advisable to give a second covering of straw on top of the soil as a protection against very severe frost. This is put on like thatch in order to prevent it being blown off. When it has to be done hurriedly a layer of strawy horse manure is often thrown on, or a covering of potato haulms applied, but both of these coverings are open to obvious objection.

### Sorting and Marketing.

The methods of sorting the crop vary in different districts according to local customs, and to the condition of the crop. Where the proportion of diseased tubers is high, hand picking may be necessary, but this is a very slow and expensive process which should be avoided if at all possible. An advance on this method is the use of hand riddles of suitable mesh, but the use of potato-sorting machines is now rapidly extending.

A modern potato-sorting machine consists of a suitable arrangement of riddles, shaking in frames, and as compared with the hand riddle it has the advantage of enabling the crop to be sorted into three or four different grades at the same time. The ware potatoes, after passing over the riddles, move on to a slowly ascending platform, from which diseased potatoes can easily be picked out, and from which the sound ware finally drops into bags. A considerable proportion of the total production of ware potatoes is loaded in bulk into railway trucks, but perhaps the greater part is first weighed up into 1-cwt. bags. In common with

other forms of agricultural produce, local systems of weights and measures are very confusing. Usually a sack of potatoes means 1 cwt., but in some cases one sack means 2 cwt., in others $1\frac{1}{2}$ or $1\frac{1}{4}$ cwt., while other measures, such as loads and barrels, are also quoted in market reports.

### Diseases.

See Insect Enemies of Root and Potato Crops, p. 272; Diseases of Root and Potato Crops, p. 225.

### Cost of Production.

See Cost of Production of Potatoes, Turnips, etc., p. 212.

### Varieties of Potatoes.

Full reference has already been made under the head of "Change of Seed" to the deterioration from which potatoes suffer, if grown year after year without change of seed in a warm, southern climate. In the same way varieties of potatoes under almost all conditions tend to degenerate slowly but surely, though there is great difference between different varieties in this respect, and it appears to be possible to check the rate of degeneration by maintaining healthy stock in a very bleak northerly situation. For instance, it is not at all uncommon to find in bleak exposed districts, old varieties apparently still healthy and vigorous though they have gone out of cultivation elsewhere. This question is one on which opinions differ as much as on that of change of seed, with which it has probably much in common. At the present time many scientific investigators are working on this problem, and it is possible that by the time this article appears in print much new light may have been thrown on the subject. Up to the present, however, no means of preventing degeneration of varieties has been found, though, as in the cases quoted above, it often appears to have been staved off fairly successfully for a considerable time.

The usual life of any variety of potato appears to be limited to some twenty years or so, though in many cases it is very much less, and, in rare exceptions, it may be extended beyond that period.

The method of raising new varieties by cross-fertilization and growing from the seeds found in the potato plum or apple is referred to in Vol. I, Improvement of Cultivated Plants, and detailed under the next heading, "Raising of New Varieties". It is only in this way that true new varieties are formed, though sub-varieties differing slightly from the original may be developed by processes of selection. The following table, taken from the *Journal of the Ministry of Agriculture*, Vol. XXVII, p. 863, illustrates the constant change taking place in the varieties grown.

| Variety. | Date of Introduction. |
|---|---|
| Victoria | 1850 |
| Regents | 1852 |
| Champion | 1867 |
| Magnum Bonum | 1876 |
| Maincrop | 1882 |
| Abundance | 1886 |
| Bruce | 1887 |
| Up-to-date | 1893 |
| British Queen | 1894 |
| President | 1901 |
| King Edward | 1902 |
| Great Scot | 1911 |
| Arran Chief | 1912 |

As already indicated the great qualities in an ideal potato are cropping power, good cooking quality, resistance to disease of all kinds, attractive appearance, and good shape and size. Naturally, also, the period at which the crop matures is a point of prime importance. These are outstanding features which are obvious to all. In addition, there are others not apparent to the consumer, but which are of some moment to the grower; for instance, the grouping of the tubers in the unlifted crop in a compact mass, so that with proper earthing up there need be no green tubers. In the case of some varieties the tubers develop at some distance from the central stem, and, almost inevitably, some are exposed to light and become useless for cooking purposes. Again, some varieties, notably the most vigorous, are particularly liable to suffer from second growth or supertuberation. It need hardly be said that it is extraordinarily difficult to combine in any one variety all the desired qualities, and there is ample room for all the effort now being expended in the attempt to evolve new kinds of superior merits.

In this connection special reference may perhaps be made to the question of disease resistance, which adds greatly to the difficulties of potato breeders. Potato blight, wart disease, and the obscure virus diseases, such as leaf curl and mosaic, are at present the most important. So far no variety has been found to be completely and permanently resistant to blight, though degrees of susceptibility vary very much. In the case of wart disease complete resistance is possible, and many of the best known varieties now on the market, including Arran Comrade, Great Scot, Kerr's Pink, Lochar, Tinwald Perfection, are completely immune to this disease. It has not yet been proved whether complete immunity to the so-called virus diseases is possible, though it is known that some varieties are highly resistant, and others highly susceptible. For instance, President and Arran Victory are subject to leaf curl; Tinwald Perfection and Irish

Chieftain specially subject to mosaic. It is, however, certain that the problem of potato diseases is one mainly for the plant breeder to solve, and at the present time there is probably no more important field of scientific investigation and research. The practice of the *best* potato growers has reached such a pitch that there is probably not much room for improvement either in methods of cultivation or in manuring, though it must be confessed that average practice lags far behind that of the best. Advance in potato growing must now mainly take the form of the production of improved varieties and the control of disease, which will, in all probability, be found to be closely associated with the question of degeneration of varieties and deterioration of seed.

**Raising of New Varieties.**

New varieties are produced from true seed, which is contained in the fruit (plum) of the potato plant. For details of the methods of cross-fertilization and natural fruiting the reader is referred to THE IMPROVEMENT OF CULTIVATED PLANTS, Vol. I.

When cross-fertilization has been effected, records of the parents should be kept; for this purpose some means of identification, such as a piece of differently coloured tape for each parent, should be attached to the stem of the plum-bearing plant.

The plums should be gathered from the plants just before the stems begin to go down, and should be put into small muslin bags—with identification labels attached—which can be left to dry in a suitable atmosphere for a few weeks. The seeds should then be extracted by squeezing the contents of the plum on to blotting-paper, and after freeing the seeds from the mucilage the former should be dried by light pressure between folds of blotting-paper and preserved for sowing in spring.

In March the seeds should be sown in a sandy mould contained in well-drained boxes or pots, and at a depth of $\frac{1}{4}$ in. in rows about 4 in. apart and 2 in. between the seeds. The boxes or pots should be put in cold frames or in a cool greenhouse. If the soil be kept damp, though by no means wet, and well aerated, the seedlings will appear in about a fortnight, when they should be protected from strong sunlight in order to prevent spindliness, by covering the frame with a piece of paper. At this stage the young plants must be well aerated. When they are about 2 in. high they should be transplanted into pots of about 4 in. diameter, and by the middle of June they will be ready for transference to ordinary soil conditions. Care must be taken throughout the process to protect the young plants from frost.

They should then be transplanted in rows, $2\frac{1}{2}$ ft. apart with 2 ft. between the plants in each drill. During the growing season they should be cultivated in the ordinary way, and notes should be made of their vegetative and floral characters and dates of maturity. On

maturity, or before the advent of frost, the tubers should be lifted and the produce of each plant kept separately in properly labelled boxes.

Selection should now be carried out. The tubers of all undesirable plants should be discarded and only those of desirable shape, colour, and constitution retained. At this stage the tubers are usually very small, often about the size of a bantam's egg.

These are planted in the ordinary way in the following year and the process of selection renewed. At this stage, too, all the varieties under investigation should be submitted to a test of immunity to wart disease, when susceptible ones should be discarded. Such practices are continued for four or five years, by which time the tubers will have increased to their normal size, cropping capacity, and cooking qualities, which improve annually during this period. If they still show characters inferior to existing types, they should be discarded, whilst if more fortunate the raiser can propagate them for market purposes.

During the period of development new varieties should not be forced as this impairs their disease-resisting powers. Further, many types may show all of the characteristics of existing types. They are thus of no great commercial use, unless they show enhanced vigour. It is seldom that a breeder of potatoes gets more than one of outstanding qualities from a thousand seedlings.

### The Maintenance of Pure Stocks of Potatoes.

It is essential that stocks of varieties of potatoes be maintained in a pure state in order that the grower may be able to depend on the ability of his chosen variety to meet special conditions, so that he may retain the confidence of the public by supplying them with tubers of uniform quality, while at the same time the spread of disease may be restrained. The spread of wart disease, which is readily carried and a source of great loss to growers, has, during comparatively recent times, made this exercise of care imperative, since many varieties are susceptible to the disease whilst others are totally immune. The latter can be grown with safety on land infected with the scourge.

It accordingly follows that there must be a satisfactory means of identifying and classifying varieties. This work has just recently been taken up in real earnest and most satisfactory results have been obtained. Previously, those who raised varieties of potatoes which were likely to meet with popular favour, put them on the market under a characteristic name without comparing them with existing varieties. It could be naturally presumed, therefore, that amongst the great many names there would be several which referred only to one distinct type. The compiled list of potato synonyms, issued by the Board of Agriculture for Scotland in 1922, confirms this view, for of 1011 named varieties, there are only

452 distinct types. The variety Up-to-date, for example, has no less than 152 names assigned to it.

The method of identifying varieties lies in the combination of features observed in (*a*) the flower, (*b*) the haulm, (*c*) date of maturity, and (*d*) the tuber. The characteristics exhibited by any one of these may not be alone sufficient to distinguish a variety, but it is usually possible to distinguish it by means of the haulm.

(*a*) *The Flower.*—Since varieties often differ in regard to the colour and morphological features, this is a great aid in recognition of types. Some, however, form no flowers, whilst many others have similar floral features.

(*b*) *The Haulm.*—The habit of growth varies amongst distinct types. Common habits are tall or low set, upright or spreading, erect or drooping, large and strong or small and weak, and bushy or straggling.

The form of the leaf also varies. The number of large and small leaflets is very variable amongst varieties, and whilst in some cases, e.g. Abundance, there is a profusion of leaflets closely set together along the midrib, in others the leaflets are set widely apart, e.g. Evergood. The former type of leaf is termed " close " and the latter " open ". The leaflets also differ in respect of their shape, texture, length of stalk, and shade of green.

In some cases, e.g. Bishop, the presence of a characteristic colour on the base of the petiole is a useful guide, as is also colour on the midrib of the leaf.

The nature of the stem is another feature in which there is much variation. The stem is usually hollow, but it may be solid, e.g. Eclipse. It may bear a characteristic colour as, for example, spots on K. of K. The " wing " (see botanical description) may be smooth and straight, e.g. Great Scot, or wavy and crinkled, e.g. Arran Chief.

(*c*) *Date of Maturity.*—Since the period tubers take to attain maturity is characteristic of the variety, this method is useful in differentiating between late and early maturing varieties when they are growing in the same field, e.g. between Epicure and Great Scot.

(*d*) *The Tuber.*—Tubers vary much in shape, colour, depth of eye, position of eyes, &c. (see " Quality "). In addition, the colour of sprout and the nature of the runners are variable features.

Tubers or potato plants found amongst a variety to which they do not belong are termed " rogues ", and the process of eliminating these is known as " rogueing ". Convenient times for rogueing are (*a*) when the tubers are being boxed, (*b*) after they have sprouted, and (*c*) during the growing season. In the last case, care should be taken to lift all the tubers of the rogue from the drill when carrying out the process and to examine the crops more than once, while the foliage is still robust, so that no rogues will be overlooked.

The prevention of mixing of varieties is an easier task and takes less time than rogueing. Consequently care should be taken to plant, harvest, and clamp varieties separately; boxes should be kept apart; clamps should not be made on land intended for potatoes; and to be safeguarded from the effects of "ground-keepers", close cropping with potatoes should be avoided.

## Classification and Descriptive Notes of Different Varieties.

Varieties are divided into three main groups according to their period of maturity, viz. First Earlies, Second Earlies, and Maincrops. The first class includes those which reach maturity between the early part and end of summer. Second Earlies are those which can be dug towards the beginning of autumn, and Maincrops include those which do not reach maturity till the end of the growing season. No strict line of demarcation can be drawn between these groups, there being gradations from one to another.

Each class is divided into "immune" and "non-immune" varieties, according to resistance to wart disease.

The accompanying table shows the popularity of the various varieties, and their tendency to lose or gain favour. It is unfortunate that similar information is not available for England and Wales, but as the Scottish farmer grows potatoes very largely with the English seed trade in view, the figures are a fairly reliable indication of the relative importance of the different varieties throughout Great Britain.

The following notes summarize the characteristics of leading and promising varieties. The descriptions of morphological features have been extracted from *Miscellaneous Publication*, No. 3 of the Board of Agriculture for Scotland. The names given in italics indicate the raisers.

### First Earlies

#### Immune

America (*Dobbie*).

*Tubers*: round; white skin; deep eyes; white flesh; pink sprouts.

*Foliage*: upright haulm, then spreading; large leaflets of bright medium green at maturity.

*Flowers*: common; mauve, tipped white.

*Remarks*: very early, fair cropper, and average quality.

Immune Ashleaf (The German "Juli"—*Paulsen*).

*Tubers*: kidney; white skin; shallow eyes on point; yellow flesh; purple sprout.

*Foliage*: medium height and spreading; indistinct wings; open, drooping leaf; long, thin, glossy leaflets.

*Flowers*: buds generally drop off; large pale blue, tipped white.

*Remarks*: average cropper; fair quality; mosaic disease common.

Dargill Early (*Gardiner*).

*Tubers*: kidney; shallow eyes; white skin; pale yellow flesh; faint pink sprouts.

*Foliage*: upright haulm; open leaf, dark, marled, glossy green.

*Flower*: seldom formed; washy lilac, tipped white.

*Remarks*: fair cropper; fair quality.

Witchhill (*Brown*).

*Tubers*: kidney; very shallow eyes; white skin; white flesh; faint pink sprouts.

*Foliage*: spreading graceful haulm; open leaf; long, dull, medium green leaflets; end leaflet drooping.

*Flowers*: seldom formed; creamy white.

*Remarks*: fair cropper; fair quality.

### Non-immune

Duke of York.

*Tubers*: kidney; flat eyes; white skin; yellow flesh; faint pink sprout.

*Foliage*: spreading haulm; open leaf; long, medium green leaflets, bright at maturity; end leaflet overlapped by last pair.

*Flowers*: seldom formed; white.

*Remarks*: not a heavy cropper; good quality; common garden potato.

*Synonyms*: Ardneil Early, Lothian Early, New Success, Victory, &c.

Eclipse.

*Tubers*: oblong to kidney; very shallow eyes; white skin; white flesh; pink sprout.

*Foliage*: spreading, straggly haulm; solid stem; round, small leaflets.

*Flowers*: uncommon; white.

*Remarks*: fair cropper; poor quality unless used early.

Epicure (*Sutton*).

*Tubers*: round; deep eyes; white skin, turning pink on exposure; white flesh; pink sprout.

*Foliage*: haulm upright and robust; pink tinge on stem; leaflets long and narrow; end leaflet drooping and overlapped by last pair.

*Flower*: not very common; white.

*Remarks*: heavy cropper; good quality; most widely grown first early.

Sharpe's Express.

*Tubers*: kidney; eyes on point small, on side have characteristic bump; white skin; white flesh; pink sprout.

*Foliage*: upright haulm; long, thin leaves; large number of bright secondary leaflets; leaflets pointed forwards and overlap.

*Flowers*: uncommon; heliotrope, tipped white.

*Remarks*: good cropper; large proportion small tubers; good quality; later than others.

## Second Earlies

### Immune

The Ally (*M'Kelvie*).

*Tubers*: round to oval, flat; shallow eyes; pale yellow skin; white flesh; faint pink sprouts.
*Foliage*: spreading haulm; dark grey-green; long, hairy, thick leaflets; secondary leaflets inconspicuous; straight wing.
*Flowers*: white; anthers generally malformed.
*Remarks*: heavy cropper; poor quality.

Arran Comrade (*M'Kelvie*).

*Tubers*: flattish round; shallow eyes; white skin; white flesh; purple sprouts.
*Foliage*: spreading to upright haulm; dark green, dull on top, bright lower down with drooping appearance; leaf open, end leaflet drooping; straight wing.
*Flowers*: fairly common; white.
*Remarks*: good cropper; very good quality; fairly early; very susceptible to blight.

Great Scot (*M'Alister*).

*Tubers*: flattish round; medium eyes; pale yellow skin; white flesh; pink sprouts.
*Foliage*: strong, tall, upright haulm; glossy, dark leaves; end leaflets droop perpendicularly; stem reddish pink at base.
*Flowers*: buds drop off very readily; white.
*Remarks*: heavy cropper; good quality; really a late second early.
*Synonyms*: Conqueror, Challenge, Invincible, Sir Douglas Haig, Southampton Wonder, &c.

King George V (*Butler*).

*Tubers*: oblong; medium eyes; white skin; white flesh; pink sprouts.
*Foliage*: spreading; open leaf, drooping gracefully.
*Flowers*: small; white; lemon-coloured anthers.
*Remarks*: good cropper; poor quality; resistant to disease.

Katie Glover (*Findlay*).

*Tubers*: round to oval; shallow eyes; pale yellow skin with carmine eyes; white flesh; pink sprouts.
*Foliage*: medium, spreading, bushy haulm; slightly crinkled wing; open leaf, terminal leaflet drooping; long, soft, glossy leaflets.
*Flowers*: hairy flower buds; pink; readily drop off.
*Remarks*: new variety; good cropper, but large proportion of small tubers; good quality.

### Non-immune

British Queen (*Findlay*).

*Tubers*: oblong; medium eyes, side eyes having a characteristic bump; white skin; white flesh; pink sprouts.

*Foliage*: rigid, spreading haulm, low set; dark green, glossy roundish leaflets.
*Flowers*: profuse; snow white; flower stalks bronze coloured.
*Remarks*: good cropper; good quality; susceptible to blight; originally very popular.
*Synonyms*: Arran Beauty, Best of All, Britannia, Fair Maid of Perth, M'Pherson, Waverley, &c.

## Maincrops

### Immune

Abundance (*Sutton*).

*Tubers*: round to oval, flat; shallow eyes; white skin; during growing season purple coloration under skin at heel end; runners have trace of blue-purple; white flesh; purple sprouts.
*Foliage*: tall, strong haulm; dark green; very close leaf.
*Flowers*: numerous and white.
*Remarks*: good cropper; good quality; an early maincrop; susceptible to blight; an old variety.
*Synonyms*: Admiral, Alton, Bountiful, Culdees Castle, Duchess of Buccleuch, Osborne Seedling, Twentieth Century, Universal, &c.

Champion (*Nicol*).

*Tubers*: round and irregular; deep eyes; white skin; purple coloration at heel end in growing season; yellow flesh; purple sprouts.
*Foliage*: erect haulm; bushy habit with profusion of thin, hard, purple-speckled stems; swollen nodes; leaflets dull, rigid, and small; open leaf; base of leaflet purple tinged.
*Flowers*: deep purple.
*Remarks*: average cropper; very good quality; very susceptible to blight; an old variety.

Crusader (*Wilson*).

*Tubers*: kidney; shallow eyes; white skin; faint pink sprouts.
*Foliage*: upright, robust, compact haulm with dark, bright, crinkled appearance; leaf is fairly close; terminal leaflet overlapped by last pair.
*Flower*: very uncommon; buds drop off.
*Remarks*: good cropper; very good quality, but large proportion of small tubers; an early maincrop; recently introduced.

Golden Wonder (*Brown*).

*Tubers*: kidney; shallow eyes; russet skin; pale lemon flesh; purple sprout.
*Foliage*: tall, vigorous, very upright haulm of unbranched stems; close leaf; leaflets crinkled.
*Flowers*: lilac, tipped white; common.
*Remarks*: fair cropper; excellent quality; stocks badly infected with mosaic.

Langworthy (*Niven*).

Same as Golden Wonder except that skin is white.

KERR'S PINK (*Henry*).

*Tubers*: round; pale pink; medium eyes; white flesh; pink sprouts.
*Foliage*: very tall, branching haulm; stem tinged pink; wavy wings; large, oblong, dark green leaflets.
*Flowers*: common; white; pale yellow anthers.
*Remarks*: heavy cropper; good quality; hardy; very liable to show second growth.

MAJESTIC (*Findlay*).

*Tubers*: kidney, but irregular; shallow eyes; white skin; white flesh; faint pink sprouts.
*Foliage*: spreading haulm; open, smooth leaf, pink tinge on midribs at early stage.
*Flowers*: profuse; creamy white; plums occur freely.
*Remarks*: good cropper; average quality; tubers do not keep well in pits.

TINWALD PERFECTION (*Farish*).

*Tubers*: oval to oblong; medium eyes; white skin; pale lemon flesh.
*Foliage*: haulm medium height, spreading, moderately vigorous; darkish green leaves.
*Flowers*: mauve, tipped white.
*Remarks*: average cropper; very good quality; stocks badly infected with mosaic.

RHODERIC DHU (*Farish*).

*Tubers*: round to oval; medium eyes; white skin; white flesh.
*Foliage*: tall, vigorous, somewhat spreading haulm; medium green leaves with well-marked veins.
*Flowers*: white.
*Remarks*: good cropper; good quality; rather late; new and promising variety.

### Non-immune

ARRAN CHIEF (*M'Kelvie*).

*Tubers*: round; medium eyes; white skin; white flesh; purple sprouts.
*Foliage*: upright, tall haulm; dull rigid crinkled foliage; open leaf; wing distinctly crinkled.
*Flower*: uncommon; white with pale green buds.
*Remarks*: heavy cropper; good quality; some stocks infected with mosaic.

KING EDWARD VII (*Butler*).

*Tubers*: kidney; shallow eyes; skin white splashed with pink; white flesh; pink sprout.
*Foliage*: erect, branched haulm; dark green, glossy leaves; youngest leaflets on top are very small, narrow, numerous, and twisted forward.
*Flower*: uncommon; mauve, tipped white.

*Remarks*: good cropper; average quality; susceptible to blight; keenly sought after in London market.

UP-TO-DATE (*Findlay*).

*Tubers*: flattish oval; shallow eyes; white skin; white flesh; faint pink sprout.

*Foliage*: spreading haulm; light green dull leaf; numerous pointed leaflets, directed forwards, last pair overlapping terminal one.

*Flowers*: common; mauve.

*Remarks*: average cropper; good quality; formerly a heavy cropper of very good quality, but these characters are now declining.

*Synonyms*: Dalhousie, Dalmeny Hero, Dalmeny Perfection, Duchess of Cornwall, Factor, Farmer's Glory, Glamis Beauty, Arran Hope, &c.

PRESIDENT.

*Tubers*: round to pebble; medium eyes; white skin; white flesh; pink sprouts.

*Foliage*: rigid, spreading haulm; broad, light green leaflets; usually only two pairs leaflets and terminal one.

*Flowers*: common; mauve-purple, tipped white; plums freely.

*Remarks*: good cropper; average quality; suitable for heavy land.

*Synonymns*: Iron Duke, Scottish Farmer.

## Utilization of Surplus Potatoes.

With a comparatively fixed consumption and a variable crop like potatoes, a favourable season always brings with it the danger of glutted markets and prices insufficient to cover the cost of production. Even if the surplus is comparatively small, it reduces prices to a disproportionate extent, as growers are afraid of having quantities left on their hands, and press their crops on the market until the price may be no higher than the estimated value of the tubers for feeding purposes on the farm.[1] In the last resort this establishes the minimum price. The position of the potato grower will thus always be precarious until some means of utilizing a surplus in a year of heavy crops is organized. At present, with the exception of a few small and unimportant starch factories, little use of potatoes is made in this country beyond their direct consumption. On the Continent, particularly in Germany, various methods of utilizing both surplus potatoes and tubers which are unfit for direct consumption have been established. The most important products are dried potatoes, potato starch, and alcohol.

A consideration of the returns to be obtained from the above and other means of utilizing potatoes is, at first sight, far from encouraging. In this country the products obtained would have to be placed on the

[1] For feeding value, see COMPOSITION AND PRODUCTS OF THE POTATO, p. 59.

market at such a low cost in order to face the competition of other materials, that the value which could be realized from a ton of potatoes would be very small. For instance, dried potatoes would have to meet the competition of foods like maize. Taking these at £8 a ton, and allowing 4 tons of potatoes to 1 ton of the dried material, the gross receipts for the original potatoes would be £2 a ton. From this has to be deducted the cost of the fuel required to evaporate about 15 cwt. of water, the labour to work the plant, and the capital charges and depreciation of the plant itself.

The calculation in the case of potato distilling is not so simple, but it may be said that, with imported petroleum products at their present price and manufacturing costs as they are to-day, the net receipts for a ton of potatoes would not be regarded by the grower as satisfactory.

The establishment of these industries by organizations of farmers would, however, probably give a handsome indirect return, provided that the hearty co-operation of all potato growers in the country could be secured. The weight of the total crop produced in any year is ascertained fairly accurately by the Ministry of Agriculture, the normal consumption is approximately known, and if an alternative market were provided to which the surplus could be diverted, prices might be maintained at least somewhere near the cost of production, and ruinous slumps would be avoided. It has been mentioned that even where such industries have been established on the Continent, the net return to the potato grower is very little, if any, higher than he would obtain by feeding the crop to cattle and pigs. This is a process well understood by the average British farmer, and pending some great development in the industrial use of potatoes it is the safest means of utilizing any unsaleable or diseased tubers.

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# COMPOSITION AND PRODUCTS OF THE POTATO

By Professor R. A. BERRY, Ph.D.(Glas.), F.I.C.

The potato plant is grown almost entirely for the tubers which it produces. The tubers not only form an almost indispensable article of human diet, but, as will be pointed out later, are also used for certain industrial purposes. In addition, potatoes are a valuable food for stock.

**Composition.**

The average composition of the potato tuber is as follows:

| | Moisture. | Crude Protein. | Soluble Carbo-hydrates. | Fibre. | Oil. | Ash. |
|---|---|---|---|---|---|---|
| | Percentage. | Percentage. | Percentage. | Percentage. | Percentage. | Percentage. |
| Tubers .. | 76·2 | 2·1 | 19·7 | 0·9 | 0·1 | 1·0 |
| Dry matter | — | 8·8 | 82·8 | 3·8 | 0·4 | 4·2 |

Water forms over 75 per cent of the weight of the tuber. Starch is the main constituent of the dry matter, and, in this respect, potatoes differ from turnips, which contain sugars in place of starch. The proportion of nitrogenous matter is small, and it is made up of about 60 per cent of pure protein; the remainder consists of substances of a non-protein nature (amides, &c.). Fibre and ash each form about 1 per cent of the tuber, whilst the amount of fat present is very small. Potatoes are therefore very largely a carbohydrate food.

The ash of potato is characterized by richness in potash salts and poorness in phosphoric acid and lime, as shown in the following figures:

| | Potash, $K_2O$. | Phosphoric Acid, $P_2O_5$. | Lime, CaO. |
|---|---|---|---|
| | Percentage. | Percentage. | Percentage. |
| Tubers .. | 0·6 | 0·15 | 0·05 |
| Ash .. | 60·0 | 15·0 | 5·0 |

One ton of potatoes would therefore contain something like 13 lb. of potash, 3¼ lb. of phosphoric acid, and 1 lb. of lime.

A regular constituent of potatoes is the poisonous glucoside, solanin, which occurs mostly in the tops or haulms and only to a small extent in the tubers. The amount present in the latter varies from 0·002 to 0·007 per cent. The higher amounts are found in unripe potatoes, and in tubers which have been exposed to light and have turned green on the surface. It is stated that heavy dressings of nitrogenous manures increase the proportion of this poison. Storage does not affect it, but when the potato sprouts, a greater part of it passes into the young shoots. This fact explains the reason why it is not advisable to feed sprouted potatoes in the raw state to stock. Potato sprouts will contain from 0·5 to 1·0 per cent of solanin. The skin contains more of this substance than the flesh of the potato.

The composition of different parts of the tuber is not uniform. Microscopical examination reveals the fact that starch is much more abundant towards the outside than in the inner part of a tuber; differences in texture are also discernible. With the naked eye it is possible to distinguish, in a section of a potato, several distinct zones of material. For example, Courdon and Bussard distinguish (1) a skin or corky covering on the inside of which is (2) a denser layer of cortical tissue surrounding (3) the central area, which consists of more translucent material. The respective proportions, by weight, of each zone in percentages is 10, 35, and 55. Frisby and Bryant, on the other hand, separate the substance of a potato into (1) a brown outer covering or cuticle which they call the outer skin, (2) an inner skin consisting of the layer immediately below. This layer contains whatever colouring matter there is in the tuber; (3) the remainder of the tuber they term flesh. The proportion and composition of the different zones is shown below

| | Tuber. Percentage. | Dry Matter. Percentage. | Nitrogen. Percentage. |
|---|---|---|---|
| Skin, outer .. | 2·5 | 19·9 | 0·43 |
| Skin, inner .. | 8·5 | 16·8 | 0·36 |
| Flesh .. .. | 89·0 | 18·9 | 0·32 |

A knowledge of the existence of these zones is obviously of importance when taking a representative sample of a tuber for analysis. For further information on this matter the reader is referred to a paper by Glynne and Jackson on the distribution of dry matter and nitrogen in the potato tuber, published in the *Journal of Agricultural Science*, Vol. IX, Pt. 3, 1919.

## Variation in Composition.

The composition of potatoes is subject to considerable variation, and the causes which bring about these changes are practically the same as those which produce similar effects upon the composition of root crops. The causes which produce variation in composition are: variety, stage of ripeness at the time of lifting, nature of soil, supply of moisture and sunshine, manuring, and period of storage.

The effect of size of tuber on the composition of the potato is shown in the following figures:

| Size. | Weight in Grammes. | Percentage Dry Matter. |
|---|---|---|
| Big .. .. | 120 | 25·9 |
| Medium .. .. | 76 | 26·2 |
| Small .. .. | 51 | 25·6 |

From the above data it is seen that size has very little influence upon the proportion of dry matter in the potato. There is, however, a connection between the percentage of dry matter and the specific gravity of a tuber. It is found that the specific gravity increases invariably with the percentage of dry matter, as shown in the following figures:

| Specific Gravity of Tuber. | | Percentage Dry Matter. |
|---|---|---|
| 1·0812 | .... | 21·43 |
| 1·0859 | .... | 22·67 |
| 1·0926 | .... | 23·67 |
| 1·0967 | .... | 24·81 |
| 1·1005 | .... | 25·6 |
| 1·1045 | .... | 26·55 |
| 1·1058 | .... | 27·57 |

The above information suggests the application of specific gravity as a means of selecting tubers with a high content of dry matter.

Again, dry matter and quality of a potato appear to be two factors very closely related. The popular idea has been that the variety Golden Wonder possessed superior qualities for culinary purposes to Arran Chief, British Queen, and Great Scot, though these latter were regarded as being of much better quality than varieties such as Evergood, King George, and Royal Kidney. A comparison of the percentages of dry matter of each variety mentioned in the following table with the remarks just made brings out the relationship.

| | Golden Wonder. | Arran Chief. | British Queen. | Great Scot. | Ever-good. | King George. | Royal Kidney. |
|---|---|---|---|---|---|---|---|
| | Percentage. | Percentage. | Percentage. | Percentage. | Percentage. | Percentage. | Percentage. |
| Dry matter | 27·24 | 23·31 | 22·39 | 22·63 | 20·83 | 21·25 | 20·74 |
| Nitrogen | 0·447 | 0·345 | 0·306 | 0·351 | 0·343 | 0·310 | 0·359 |

Seeing there exists a close connection between dry matter content and quality in potatoes, information as to the percentage of dry matter in each of the numerous varieties of potatoes now on the market is a matter of first-rate importance. It would also prove useful if the percentage of dry matter of new varieties were ascertained before they are put on the market.

In the many hundreds of varieties of potatoes in cultivation decided differences in external characters, &c., are distinguishable. Among these differences may be mentioned size, shape and colour of tuber, cooking and keeping qualities, susceptibility to disease, early or lateness, cropping capacity, &c. Unfortunately figures respecting the percentage of

dry matter and other chemical data are lacking for a large number of varieties. Sufficient information, however, is available to show that considerable differences in dry matter between varieties exist. Russell finds that the extreme limits for dry matter in the ordinary varieties on the market range from 17·6 to 29·1 per cent, average 22·09, whilst the percentage of nitrogen varied from 0·204 to 0·526, average 0·327. He also made a comparison of the dry matter content of some immune with some non-immune varieties, and found that practically no difference in composition existed between them. No disadvantages in feeding value would therefore appear to follow the substitution of an immune for a non-immune variety, a point of considerable public importance.

The range of variation in the composition of potatoes given by Dietrich and König is as follows:

| | Water. | Proteins. | Soluble Carbo-hydrates. | Fibre. | Oil. | Ash. |
|---|---|---|---|---|---|---|
| | Percentage. | Percentage. | Percentage. | Percentage. | Percentage. | Percentage. |
| Minimum | 68·03 | 0·83 | 19·45 | 0·28 | 0·04 | 0·53 |
| Maximum | 84·9 | 3·66 | 22·57 | 1·57 | 0·96 | 1·87 |

It is stated that rough-skinned tubers are mostly richer in starch than the smooth-skinned ones, and also that the yellow-skinned varieties are somewhat richer in dry matter and starch than the red-skinned varieties. Early varieties are, as a rule, not only lighter croppers, but usually more watery than late varieties. However, the information is too scrappy and limited to allow of an accurate discussion being made on these points.

To refer briefly to other factors which influence the composition of the potato, it is well known that the composition of the tuber changes as the tuber develops. The following figures illustrate the point:

| | 9th July. | 7th August. | 10th September. |
|---|---|---|---|
| | Percentage. | Percentage. | Percentage. |
| Tuber, dry matter .. | 13·48 | 20·98 | 23·31 |

Growth of the tuber, therefore, produces a gradual increase in the amount of dry matter; the increase, at first, is due mostly to starch, but later there is in addition an appreciable increase in protein matter.

The soil is an important factor in determining quality in the potato. As an outstanding example of this, the red soil of Dunbar may be mentioned. This soil grows the finest quality of potatoes in Britain, but exactly what constitutes the special property in this soil or to

what extent the climatic conditions contribute towards the result has not been established. As a rule the best quality potatoes are grown on the lighter soils, provided that the temperature is suitable and the rainfall is sufficient to keep a moderate and uniform supply of moisture in the soil.

As regards the effect of general climatic conditions on the potato, in an experiment carried out in connection with the Ministry of Food it was found that dry matter of potatoes grown in the eastern counties of England was 1 per cent more than that of the same varieties grown in the western counties. The assumption is made that the variation represents the effect of differences in rainfall.

Manuring, suitably carried out, improves both the yield and the quality of potatoes. This result is particularly noticeable when potash manures have been applied. When the supply of this ingredient in the soil is inadequate, both the yield and the quality of the potato rapidly falls. Excessive manuring, on the other hand, although it produces increased yields, is detrimental to the quality of the potato. This effect is observed more particularly when heavy dressings of nitrogenous and farmyard manures are applied. Varying results with potatoes have been obtained by the use of different salts of the same manurial ingredients, such as, for example, the chloride and the sulphate of potash. It may so happen that the chloride costs less per unit of potash than the sulphate or vice versa. It is, therefore, important to determine the actual manurial value of the chloride compared with the sulphate, a point which is now receiving careful experimental tests.

So far, however, it is noteworthy that artificial mixtures of potassium chloride and common salt together with low grade natural salts have caused stunted development in the early stages of growth when the season is dry. After heavy rains, however, the plants soon recover. The chloride seems to give a lighter coloured foliage and hastens the maturing processes in plants, thus causing the yellowing and drying off of the haulms to be somewhat earlier than where no chlorides were supplied. As to the question of quality, the results suggest that excessive chloride applications are distinctly detrimental to quality. In the cooking tests it was also shown that high chloride content of the potato led to watery and discoloured tubers.

With potatoes intended for human consumption the boiling qualities are perhaps the first consideration. Good quality potatoes, after boiling, should be mealy and should not blacken on keeping. The question as to the cause of the blackening is one which has not yet been satisfactorily explained.

In concluding these brief observations upon the factors which produce change in the composition of potatoes, it seems necessary to refer again to the fact that dry matter as an indicator of quality and feeding value

should be taken into account in the selection of potatoes for cultivation. Hitherto cropping capacity has been too often taken as the basis of selection to the exclusion of other considerations, except perhaps the question of immunity to disease.

### Loss on Storage.

During storage potatoes steadily lose weight, owing mainly to the evaporation of water and to a less extent to the oxidation of starch involved in the respiration of the tubers. The total loss in weight during storage commonly reaches 10 per cent, and under certain circumstances may greatly exceed this amount.

### Nutritive Value.

Potatoes are mostly disposed of for human consumption. When, however, the price falls so low that they can be as economically utilized in the feeding of stock, the crop forms a valuable addition to the other foods of the farm.

The point now to consider is the digestibility and feeding value of the potato. As already remarked, starch forms over 80 per cent of the dry matter of the potato; for this reason the potato ranks very high in digestibility. Warrington gives the average digestion coefficient to be as follows:

Digested for 100 of each Constituent Supplied

| | Organic Matter. | Crude Protein. | Soluble Carbohydrates. | Fibre. |
|---|---|---|---|---|
| Ruminants .. | 88 | 66 | 93 | — |
| Pigs .. .. | 93 | 73 | 98 | 55 |

The digestion is effected with little expenditure of energy on mastication, &c., compared with the expenditure required in the case of the digestion of foods containing much fibre.

In the feeding of potatoes to cattle it must be borne in mind that their richness in carbohydrates makes them specially suitable as a food for fattening animals, since the requirements of such animals are largely met by carbohydrates. Their poverty in proteins and lime, however, renders them unsuitable to form more than a small proportion of the ration for young stock. In practice the best results with potatoes are obtained in the fattening of pigs and cattle, especially the former. For fattening pigs, potatoes can be used to advantage as *part* of a properly balanced ration, when 4 lb. of potatoes are roughly equivalent to 1 lb. of meals. They may also be fed to dairy cows and fattening animals as

part of the ration, but the amounts given should not exceed 28 lb. per day. Sheep also benefit from small amounts of potatoes, but care should be taken in the use of them. When fed to horses they must be given in very small quantities, and great discretion must be exercised when substituting them for part of the ordinary ration.

Raw potatoes possess a peculiar sharp taste and exercise a somewhat irritating and laxative effect on the digestive organs, and, when fed in large quantities, they cause purging and colic. For this reason the foods fed along with raw potatoes should not possess marked stimulating properties, such as in the case of molasses and malt coombs, &c. Milder acting foods such as the oil cakes are preferable. The potatoes fed should be sound and clean, adherent dirt should be washed off; otherwise continued consumption of earthy matter may cause inflammation of the bowels, &c. Pigs are more sensitive than other farm animals to the ill-effects which may occur from eating raw potatoes; hence, it is the invariable practice to boil or steam potatoes required for pig feeding. Boiling destroys the laxative character of the potato. For cattle, however, if the potatoes are sound and are fed in reasonable quantities it is not necessary to boil them. But diseased or rotten potatoes must be boiled before feeding to any kind of stock. Care must be taken in the feeding of unripe and sprouted potatoes as they contain more of the poisonous substance solanin. In this case the sprout and green tubers should be removed before feeding.

### Potato Tops or Haulms.

The potato tops or haulms have the following percentage composition:

| Moisture. | Protein. | Soluble Carbo-hydrates. | Fibre. | Oil. | Ash. |
|---|---|---|---|---|---|
| Percentage. | Percentage. | Percentage. | Percentage. | Percentage. | Percentage. |
| 77·0 | 2·5 | 10·2 | 6·2 | 1·0 | 3·1 |

The presence of appreciable amounts of solanin makes the potato tops unsuitable for feeding purposes. As a rule they are returned to the soil, to which they supply organic matter.

### Products of Potatoes.

**Dried Potatoes.**—Owing of late years to a tendency to grow more potatoes than is required for human consumption and other purposes, drying the surplus potatoes instead of allowing them to go to waste is practised. On the Continent, especially in Germany, a large number of drying installations have been set up. The following two drying processes are mainly adopted: (1) after washing and slicing, the potato is dried in

rotating drums through which hot air is blown; (2) the potatoes are boiled and chopped into small pieces which are pressed between revolving rollers heated internally with steam, when the adhering potato dry matter is scraped off and broken into flakes.

The dried potato keeps well, and the nutritive value appears to be little impaired by the process of drying. It is suitable for all stock, and provided that the process is an economical one, a future is predicted for this material. Its analysis is as follows:

| Moisture. | Soluble Carbo-hydrates. | Fibre. | Crude Protein. | Fat. | Ash. |
|---|---|---|---|---|---|
| Percentage. | Percentage. | Percentage. | Percentage. | Percentage. | Percentage. |
| 12·0 | 74·0 | 2·3 | 7·4 | 0·4 | 3·9 |

## Potato Starch and Alcohol.

Potatoes are also used for the manufacture of starch and alcohol. From the former process potato pulp, and from the latter process potato slump, are produced as by-products.

**Potato Starch,** and that obtained from maize and rice, is used almost exclusively for laundry purposes, for manufacturing processes such as the sizing of paper and of cotton goods, and for the manufacture of British gum. Starch for edible purposes is obtained from other well-known sources. The starch grains of the potato vary much in form, the smaller ones being more or less spherical, whilst the larger ones are ovate or oyster-shell shaped. In the larger ones the concentric rings are very distinct and complete.

**Alcohol** obtained from starch is the ethyl or vinous alcohol, commonly called spirits of wine.

*Potato Pulp* is the residue left after the extraction of most of the starch from the potato and consists mostly of cellular tissue and adhering starch, along with some protein matter. In the fresh condition it contains about 86 per cent of water, 0·6 per cent of crude protein, about 11·5 per cent of soluble carbohydrates, and from 1½ to 2 per cent of fibre. Owing to the rapidity with which it ferments it cannot be stored, and must therefore be used without delay. It is used in the feeding of cattle, cows, and pigs. Its digestibility is inferior to that of potatoes.

*Potato Slump* consists of the residue left after the manufacture of alcohol from potatoes. (For process of manufacture the reader should consult books on industrial chemistry.) In the fresh condition it contains about 95 per cent of water, 1·25 per cent of protein, from 3 to 5 per cent of soluble carbohydrates, and about 1 per cent of crude fibre. Like the above-named product it decomposes rapidly and must be used at once. It is a useful food for cattle. Owing, however, to the presence of small

quantities of acids, it must be used with a certain amount of caution; otherwise its consumption may give rise to looseness or other troubles, arising from the irritating action upon the digestive organs.

Both of the above products, when dried, keep well, but the cost of drying makes the practice prohibitive. The following is an average composition of each in the dried state.

| | Moisture. | Soluble Carbohydrates. | Crude Protein. | Oil. | Fibre. | Ash. |
|---|---|---|---|---|---|---|
| | Percentage. | Percentage. | Percentage. | Percentage. | Percentage. | Percentage. |
| Potato pulp | 14·0 | 65·2 | 3·4 | 0·1 | 8·8 | 5·5 |
| Potato slump | 10·0 | 40·8 | 24·3 | 3·7 | 9·5 | 11·7 |

# THE TURNIP CROP

By WM. RIDDET, B.Sc.(Agric.), N.D.A.(Hons.), N.D.D.(Hons.)

After the introduction of modern agricultural practices the turnip crop soon attained a position of pre-eminence amongst the so-called root crops. This rise in popularity aided in raising the standard of British farming very materially, and provided a widespread stimulus for improvement by agriculturists, as may be gleaned from a review of the history of the crop.

Contrary to common belief, the nature and virtues of the turnip were known to the Greeks and Romans; Columella, the famous agricultural writer of the first century, refers to the use of the turnip in Gaul, both as a table vegetable and as a cattle food during the winter months. Throughout the early and middle ages, however, the extension of its cultivation to field conditions was not carried out, in all probability due to the bellicose nature of the times, the unfavourable systems of land tenure, and the want of enclosed lands which could safeguard such an easily damaged crop from the wanderings of the common stock. It was mainly prized as a garden vegetable until the end of the sixteenth century, although a few people in England and more in France and Holland fed it to stock. In the later part of the sixteenth century improved methods of farming, involving the use of turnips and clover, afforded so much success to farmers in the Low Countries that Sir Richard Weston, who had spent some time in these lands, was so impressed by the improvements that on his return to England he published details of these in a book entitled *A Discourse of Husbandrie in Brabant and Flanders*. This not only defeated the hitherto existing conviction that garden practices could not be applied to farming conditions, but also created an interest in the adoption of the crop. Yet it fell to the lot of Lord Charles Townshend (1674–1738), on his retiral from political office, really to draw the attention of farmers to the merits of the Continental system, which he had himself studied at first hand, by

successfully growing the crops on his estate at Raynham, in Norfolk. His work proved to the farming community that the adoption of a four-course rotation improved the fertility of the soil, thereby increasing the yield of crops, and provided a means both of maintaining stock more economically and of even fattening animals in winter, which had previously been an insuperable problem to the stock owner. The extent of the popularity of such a revolution in methods may be realized from the report that between 1720 and 1730 the system was carried into effect as far afield as West Lothian by the second Earl of Stair. The turnip crop, along with the other new crops, thereafter gradually gained the confidence of farmers, till, by the early part of the nineteenth century, it was practically regarded as an essential part of any system of cropping.

Meantime a distinct yet similar species of Brassica came into cultivation in Britain in the form of the Swedish turnip. The spread of this plant had its beginning in a packet of seed sent from Gothenburg in Sweden, in 1777, and, on account of its better keeping and feeding qualities, soon rivalled its sister crop in extent of cultivation. For many years the swede was grown with a certain degree of scepticism on account of its firmer texture and its requiring to be sown earlier in the year, which necessarily reduced the cleaning period of the ground. However, these objections were gradually waved aside, and now we have the swede and common turnip replacing each other and spoken of as the "Turnip Crop", each used in accordance with the demands of the soil and climate and with the purpose for which grown.

Whilst the growth of the crop was engaging the earnest attention of so many minds, it is not surprising that the initial system of cultivation should undergo drastic changes. At first, in some instances, seed was broadcasted after the barley crop had been sown, with the object of affording some keep for stock after harvest. But the general custom was much different. The land was first ploughed in April, again in May, and well harrowed twice before broadcasting the seed at the rate of 2½ lb. per acre, between the months of June and August. The seed was covered in with a short-tined harrow and rolled with a wooden roller. When the plants had attained the rough-leaf stage, the land was hoed by hand and the plants singled to distances apart of from 5 to 8 in. A second hoeing was performed a month later, when the plants were further singled to from 12 to 15 in., the greater distance for turnips intended for cattle feeding. This system demanded the sole use of hand labour, and had the grave disadvantage of encountering much difficulty in restraining the growth of weeds. Fortunately, these drawbacks were soon overcome, for, just prior to this, Jethro Tull had introduced his famous system of drill husbandry, and, along with many others, including Townshend, applied his system to the cultivation of the turnip crop with much success. It is worthy of note that the distance between the drills

varied from 3 to 6 ft.; strange to say, Tull got the best results from a width of 6 ft.

The drill system not only had the advantage of growing larger crops and keeping the ground cleaner, but it also made possible the adoption of horse cultivation to the inter-drill cleaning operations. The extension of drill cultivation made slow progress in the south and midlands of England. It was in the north of England and south of Scotland that the system advanced most rapidly. There experience proved that the width of the drills recommended by Tull was far too great, and a gradual reduction to that of modern times took place. By the middle of the nineteenth century the advantages of sowing seed on raised ridges in the wetter districts of the country were observed, and there sprang up the present-day custom in the northern parts of the country of sowing on raised ridges, whilst sowing on the flat is still practised in the drier regions of the south.

Time has also witnessed much change in the manuring of the crop. At first no manures appear to have been applied, but in the latter half of the eighteenth century the practice of applying farmyard manure, composts of farmyard manure and earth, marl, coombs, and rape cake sprang up. With the extension of shipping and a greater variety of artificials, in the first half of the nineteenth century guano and bones were freely used, and these in turn were soon replaced to a greater or less extent by dissolved bones, superphosphate, and nitrate of soda. Advances in agricultural science have now placed a still wider variety of fertilizers at the disposal of growers, thus making it possible for good crops to be raised under varying conditions of soil and climate, provided that proper methods of tillage be adopted.

The crop has been subject to both fungoid diseases and insect pests since its introduction to field cultivation. There are numerous references in agricultural literature to the damage caused by finger-and-toe disease (formerly known as Anbury), mildew, and the ravages of the turnip fly. The spread of finger-and-toe became so serious towards the middle of the nineteenth century that numerous premiums were offered for a proper system of controlling it, but it was only at the end of the century that the real cause of the trouble was discovered. Even yet this pestilent disease remains with us, and, along with many others, gives rise to much difficulty in the growing of good crops.

The history of the emergence of varieties is no less interesting and instructive to present-day improvers of the turnip than the evolution of the systems of cultivation is to the grower. When known as a garden crop only two varieties existed under the names of Navewe and Neep, the latter term being still common in some parts of the north. The former variety was tankard-shaped and the latter globular. In his *Herbal* (1597), Gerarde described further varieties and in particular referred to " Rapum

Majus which grew in fields and divers vine-yards or hoppe gardens" and "Rapum Minus which excelled all the others in flavour". On extension to field cultivation the number of varieties naturally increased through casual selection and importation of seed from the Continent. In 1767 the following distinct varieties were commonly grown: the Round Red or Purple Topped, the Green Topped, the Yellow, the Black Rooted, the Long Rooted, and the Early Dutch. All of these with the exception of the Yellow had white flesh. The Green Topped was considered the best on account of its larger size and better keeping qualities. The Purple Topped was also held in high esteem, but it had the objectionable feature of becoming stringy with age. The Early Dutch was grown solely for early sale as a vegetable. The other varieties were believed to be inferior in quality and yield. By the beginning of the nineteenth century the Purple Topped and Black Rooted varieties had practically fallen out of cultivation, whilst two new varieties, namely the White Topped and the Stone, had been introduced. The Stone was believed to produce the best feeding quality though the smallest roots; the White Topped was largely grown in the best turnip districts. The Green Topped, however, continued to be favoured, while the Yellow had not been sufficiently widely tried to give true evidence of its merits. The Long Rooted variety came to be known as the Tankard and was valued for early sheep folding, but its peculiarity of growing high above the ground caused it to lose favour for folding in winter. When first introduced there appear to have been two varieties of Swedish turnips—a white and a yellow.

During the eighteenth century increased attention to the selection of turnips and swedes to suit all conditions of climate and soil was reflected in the rapid multiplication of varieties on the market. Morton's *Encyclopædia* (1855) describes eleven varieties of swedes, ten green-topped yellow, three purple-topped yellow, seven white, six green-topped white, and four red-topped white turnips. By this time the improvement in varieties had given rise to better crops than those grown at the beginning of the century, and the once-popular red tops were restricted to use on poor soils and for early disposal. From that time to the present day certain seedsmen have continually striven to improve existing strains in regard to yielding qualities and disease-resisting powers. As a result, the names of turnips and swedes on the market have multiplied to the extent of utter confusion, for many distinct names are really those of one variety. It is therefore fortunate that, within the last few years, an organized effort has been instituted to classify all existing varieties, as has been so successfully done with potatoes. In this way within a few years it will be possible to state, with more degree of accuracy than at the present time, the usefulness of particular varieties under varying conditions of soil and climate.

## The Extent of Cultivation.

The turnip crop is cultivated in almost all temperate parts of the world not subject to long periods of drought. Where there is a danger of this it is replaced by the more drought-resisting mangel or by forage crops. It is never grown for export, and it is only in exceptional circumstances, such as the proximity to large vegetable markets, that it is not consumed on the holdings where it has been grown, for in spite of its great nutritive value, the large percentage of water makes transport uneconomical; yet, as the statistics shown below prove, it plays a most important part in farming economy. This is due to the fact that the crop is grown while the land is being thoroughly cleaned and thrown open to nature's restorative agents, and to its high value as a food for stock.

## Area under Turnip Cultivation in the British Isles.

The extent to which the crop has been cultivated and its relation to other crops since 1866 is shown in acres in the following table.

TABLE I

| Year. | England. | | Wales. | | Scotland. | | Ireland. | |
|---|---|---|---|---|---|---|---|---|
| | Turnips and Swedes. | Total Arable Land. | Turnips and Swedes. | Total Arable Land. | Turnips and Swedes. | Total Arable Land. | Turnips and Swedes. | Total Arable Land. |
| 1866 | 1,610,610 | 13,238,710 | 62,442 | 1,026,953 | 478,990 | 3,265,294 | 317,198 | 5,520,568 |
| 1871 | 1,592,933 | 13,835,827 | 69,833 | 1,110,352 | 500,978 | 3,456,946 | 327,035 | 5,621,437 |
| 1881 | 1,478,682 | 13,008,112 | 66,356 | 969,550 | 490,604 | 3,300,680 | 295,212 | 5,195,375 |
| 1891 | 1,367,960 | 12,028,226 | 70,607 | 875,359 | 479,568 | 3,581,079 | 300,326 | 4,818,381 |
| 1901 | 1,144,035 | 11,236,592 | 61,934 | 881,697 | 458,556 | 3,471,907 | 289,759 | 4,631,051 |
| 1911 | 1,066,625 | 10,574,922 | 57,947 | 724,288 | 438,818 | 3,348,568 | 270,805 | 4,861,224 |
| 1914 | 989,523 | 10,306,467 | 55,571 | 591,787 | 430,608 | 3,295,487 | 276,872 | 4,815,265 |
| 1915 | 881,103 | 10,272,673 | 50,753 | 693,034 | 420,995 | 3,289,902 | 265,122 | 4,900,210 |
| 1916 | 885,477 | 10,302,153 | 52,682 | 748,948 | 414,320 | 3,303,741 | 262,814 | 4,806,575 |
| 1917 | 921,553 | 10,454,149 | 50,821 | 791,957 | 414,305 | 3,360,562 | 293,452 | 5,570,592 |
| 1918 | 858,516 | 11,463,679 | 52,302 | 934,961 | 396,689 | 3,453,495 | 294,795 | 5,709,912 |
| 1919 | 925,579 | 11,412,353 | 57,819 | 896,523 | 426,451 | 3,408,479 | 273,460 | 5,326,437 |
| 1920 | 935,786 | 11,180,322 | 55,622 | 839,423 | 425,255 | 3,380,237 | 276,507 | 5,251.242 |
| 1921 | 845,015 | 10,843,512 | 49,995 | 774,724 | 410,789 | 3,349,067 | 265,599 | 4,880,030 |
| 1922 | 775,212 | 10,583,258 | 45,916 | 727,257 | 404,112 | 3,338,068 | 247,881 | 4,987,975 |

It is evident that there has been a gradual decline in the area under the crop since 1866, with the exception of the period of the Great War. This decrease is much more distinct in England than in Scotland. In reviewing these figures it must be remembered that the total extent of land under cultivation has fallen from a period of high farming in 1866 to one of post-war depression in 1922. Consequently, consideration of

the area under the turnip crop in relation to that under other crops shows that it still maintains a position of importance amongst our common farm crops. This is indicated by the figures in the following table.

TABLE II.—THE TURNIP CROP IN TERMS OF PERCENTAGE OF TOTAL ARABLE LAND

| Year. | England. | Wales. | Scotland. | Ireland. |
|---|---|---|---|---|
| 1866 | 12·2 | 6·1 | 14·6 | 5·7 |
| 1914 | 9·6 | 8·1 | 13·0 | 5·5 |
| 1922 | 7·8 | 6·3 | 12·1 | 4·8 |

The proportion of land under turnips has remained fairly constant in Scotland and Wales. On the other hand there is a distinct reduction in England. This does not correspond with the variation in the number of sheep and cattle, for, though the former decreased from 15,124,541 in 1866 to 13,438,020 in 1922, the latter increased from 3,307,034 in 1866 to 5,722,661 in 1922. These statistics reveal rather an anomalous position when it is realized that cattle consume a much larger weight of turnips per head than sheep (roughly, four or five times as much). The explanation probably lies in (*a*) the adoption of a more economic use of turnips by feeding them along with concentrated foods, and (*b*) their displacement to some extent by more recently introduced and improved forage crops.

Considering green crops by themselves, the turnip crop is cultivated to a far greater extent than any other, especially in Scotland and Wales, as is shown in the following table.

TABLE III.—AREA UNDER GREEN AND FORAGE CROPS IN GREAT BRITAIN, 1922

| Crop. | England. | Wales. | Scotland. |
|---|---|---|---|
| | Acres. | Acres. | Acres. |
| Turnips and swedes .. .. | 775,212 | 45,916 | 404,112 |
| Potatoes.. .. .. .. | 536,244 | 24,933 | 157,404 |
| Mangel .. .. .. .. | 411,126 | 11,515 | 2,008 |
| Cabbage, kohl-rabi, and rape.. | 127,186 | 9,590 | 14,920 |
| Vetches and fodder crops .. | 135,285 | 894 | 9,564 |
| Lucerne .. .. .. .. | 50,466 | 164 | — |
| Sugar beet .. .. .. | 8,404 | 6 | — |

It is evident from Table III that the turnip crop accounts for a greater area of the root break in Scotland and Wales than all the others taken together. This supremacy is very largely due to the nature of the climate.

As a result of variations in climatic, topographical, and local economic conditions, the distribution of the crop is not uniform throughout each country. The most important turnip-growing counties are enumerated in the following table.

TABLE IV

| County. | Turnips and Swedes. Acres, 1922. | Total Arable Land. Acres, 1922. |
|---|---|---|
| *England.* | | |
| Northumberland | 27,729 | 187,350 |
| Cumberland | 24,865 | 189,899 |
| Dorset | 22,376 | 158,709 |
| York: East Riding | 63,967 | 455,571 |
| ,, North Riding | 44,513 | 346,618 |
| ,, West Riding | 42,090 | 368,113 |
| Norfolk | 84,895 | 779,468 |
| Salop | 23,417 | 225,814 |
| Nottingham | 21,042 | 225,124 |
| Lincoln (parts of Lindsey) | 55,125 | 556,228 |
| ,, (parts of Kesteven) | 20,138 | 265,616 |
| Devon | 35,851 | 487,185 |
| Hampshire | 28,448 | 346,419 |
| *Scotland.* | | |
| Aberdeen | 81,748 | 597,362 |
| Forfar | 29,741 | 224,098 |
| Perth | 24,348 | 239,343 |
| Berwick | 21,466 | 142,464 |
| Fife | 29,741 | 177,170 |
| Banff | 20,106 | 149,820 |
| *Wales.* | | |
| Denbigh | 6,372 | 86,122 |
| Glamorgan | 5,103 | 55,503 |
| Radnor | 4,673 | 38,573 |
| Montgomery | 4,656 | 69,755 |
| Pembroke | 4,258 | 95,209 |
| Brecon | 3,836 | 37,559 |

It must not be presumed that turnips and swedes are not grown in the other counties. Indeed they are to be found in every county of the country. In relation to other crops they are least grown in the south-eastern and Home counties of England, where, especially on the heavier land,

they are replaced by mangels and kohl-rabi. The reasons for such a distribution as this, will be more readily understood after study of the relation of climate and soil to the growth of the crop.

In all the tables which have been shown, turnips and swedes are treated collectively in accordance with the returns prepared by the Ministry of Agriculture. To assign particular districts to either of those is a very difficult matter, because the swede freely replaces the turnip and vice versa. Generally speaking, when grown as a main crop swedes are more favoured in the south of England, but when used as a catch crop the turnip is the more common. In other parts the turnip and swede replace each other according to local needs.

**Botanical Features.**

The turnip belongs to the natural order *Cruciferæ*, which embraces many cultivated vegetables and flowering plants, in addition to several very obnoxious weeds such as the runch (*Raphanus Raphanistrum*) and charlock (*Brassica Sinapis*). As indicated above, there are two species of turnips, namely the common turnip (*Brassica Rapa*) and the swede turnip (*Brassica Rutabaga*). No strict line of demarcation can be drawn between those two species as natural crossing takes place freely, a feature which presents much difficulty to the seed grower. In their botanical affinities the common turnip is usually regarded as a variety of rough-leaved rape, whilst the swede is believed to be a variety of the smooth-leaved rape. As a type for descriptive purposes the common turnip will be taken, and references will be made later to the points of distinction in the swede.

The seed is about two millimetres in diameter, purplish red in colour, round in shape, and, when closely examined, exhibits a netted surface covered with dots. It is of the non-endospermic type. The embryo is so arranged that the cotyledons lie folded longitudinally with the radicle placed dorsally within the fold of the cotyledons.

The seedling consists of three distinct parts: (1) the primary tap-root which at first grows most rapidly of the three and follows a downward course into the soil: (2) the cotyledons which have emerged from within the seedcoat and have been projected above the level of the ground to function as the first green leaves; these are smooth, medium green in colour, and possessed of a characteristic notch at their tips; between the bases of the stalks of the cotyledons lies a bud which later gives rise to the stem and foliage leaves of the mature plant: (3) the hypocotyl, which is the region between the cotyledons and the tap-root, and has served to raise the cotyledons above the ground.

By the time cotyledons are visible the seedling has attained a stage at which it must depend on the elaboration of its own food materials. From a week to ten days after these have made their appearance above

the ground the first foliage leaf appears. This, when full grown, is grass green in colour, somewhat roundish in shape, with a hairy surface and little projections along its margin. The plant may be mistaken at this stage for the seedling of charlock, but can be distinguished by its smaller first foliage leaf.

Till nearly full-grown the turnip continues to produce more leaves above ground, and at an early age starts to swell that part underneath the level of the soil, commonly known as the " root ", but more strictly speaking, the storage organ.

## Mature Plant of the First Year's Growth.

During the first year the materials elaborated in the leaves are accumulated in the storage organ. This storing tissue is contained in both the original hypocotyl and upper part of the tap-root, each of which has become much enlarged, radially and longitudinally. For the carrying out of the manufacturing process a profusion of foliage leaves has been produced. These are borne on a distinct crown which really consists of a very much contracted stem. Each leaf is light green in colour, hairy, pinnatifid in form, and possessed of a stalk or petiole of varying length. The colour of the storage organ above ground is a feature which differs with variety, common types being white, green, purple, red, and mottled. The proportion of hypocotyl to root within the storage organ is by no means the same for each variety, but the root can always be clearly distinguished by its giving off branch roots which permeate the soil in all directions, thereby increasing the food area of the plant.

At the end of the first year's growth the foliage leaves turn yellow, indicating that the plant has now reached a stage of maturity at which the storing of nutrients has ceased. Under ordinary circumstances the turnips are used at this stage for feeding to stock.

Swede showing second year's growth with production of seed.

## Second Year's Growth.

In the second year the turnip lays up no food materials in the storage organ. On the other hand it specializes in the production of abundance of seed. This is made possible by the utilization of the reserves in the storage organ collected during the previous year.

In the spring the contracted stem of the previous year gradually

lengthens out to a height of about 3 ft., and bears numerous lanceolate smooth leaves, the bases of which clasp the stem. Towards midsummer a profusion of pale yellow flowers is produced in succession from the lower part of the inflorescence upwards. These flowers possess all the characteristic features of the order to which the plant belongs. After pollination and fertilization have been effected, the fruit is produced. Each mature fruit is a long smooth siliqua.

Since the food materials originally saved up in the storage organ are used for the production of seed during the second year, it is only when a crop is grown specifically for seed that it is kept till the following year. Sometimes, however, unfavourable conditions such as the incidence of late frosts cause the plant to produce flowers and seed in the first year of its growth instead of filling up the storage organ with elaborated food materials. Plants doing this are said to have " bolted ".

**Types of Turnips.**

There are two main types of common turnips, namely the White and the Yellow.

The White Turnip differs from the Yellow in having its flesh and the portion of the storage organ below the level of the ground white in colour. The colour above ground is very variable (see notes on varieties). This is the most rapid grower of all types of turnips, and is accordingly last sown, first harvested, and commonly ready for use early in September. It suits a wider range of soil than the others, and can be grown with a fair measure of success in exposed districts and on poor sandy soils. It, however, is the least hardy type of all, and, being extremely susceptible to the destructive effects of frosts, must be consumed if mature before the onset of winter. Besides, it is less nutritious than the other types on account of its high water content, which sometimes reaches as much as 94 per cent. It bears a large proportion of foliage, amounting often to 20 per cent of the total weight. With age its roots become very stringy, and unless eaten off when they attain maturity are very liable to rot. White Turnips are unsuited for storage during winter. The average percentage of dry matter in this type is about 8·3.

The Yellow Turnip is so named from the colour of its flesh and of the skin of that part of the storage organ below the level of the ground. It was formerly believed to be a hybrid between the White Turnip and the swede, but modern research in crossing these disproves this assumption. The colour of the upper part of the storage organ varies with variety from green to purple. It is a less rapid grower than the White, and must be sown at an earlier date. However, it is hardier and resists frost to a much greater extent. Indeed, certain strains are particularly resistant to winter conditions. Its flesh is firmer than the White on account of its lower water content and it possesses a higher feeding value. The

average percentage of solids is roughly 9·6. The pale yellow-fleshed varieties contain less dry matter, indeed much the same as the Whites. Thus White Turnips and pale yellow-fleshed types of Yellows are spoken of collectively by some as Soft Turnips in contradistinction to Yellows and swedes. The Yellow has a smaller proportion of leaf surface than the White. It is particularly suited to sandy loams which are too light for the better quality swedes. But it is unsuited to the lightest kinds of soils, on which White Turnips can be alone expected to grow with any measure of success.

Both White and Yellow Turnips are less resistant to disease than swedes, Whites being least resistant of all. They are also shallower rooted.

## Features in which the Swede Turnip differs from the Common Turnip.

(1) The seed of the swede is larger and much darker than that of the common turnip; it is indistinguishable from that of rape. (2) The first foliage leaf is hispid like the Yellow, but much less so, and is of a waxy bluish green colour; the later leaves are smooth and glaucous. (3) It has a distinct neck, i.e. the stem is slightly more protracted than that of the common turnip. (4) The flowers are usually pale orange in colour. (5) The proportion of leaf to root in the swede runs about 15 per cent, being rather less than the White or Yellow (6) It has a deeper root than the common turnip.

The swede is the hardiest of all types of turnips, being the most resistant to frost and disease. Its flesh is much firmer than that of the others, varying with variety from white to yellow in colour. The white-fleshed types have coarse irregular roots, thus the finer-shaped yellow-fleshed are those mostly cultivated. The swede has a much higher food value on account of its lower percentage of water; it contains about 12 per cent of dry matter. Both the carbohydrate and protein constituents are higher. Growth, however, is much slower than with the common turnip, and sowing should be at an early date. It also requires a better class of soil, and produces its highest yields on deep rich land and clay loams. It is quite unsuited to the lighter soils, but can be grown with a fair degree of success on the heavier classes. As a main crop it is the type which is most widely cultivated in Britain.

## The Desirable Features of a Good Turnip or Swede.

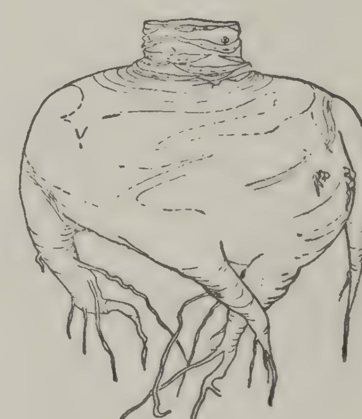
(1) A good turnip should be productive of a large amount of dry matter per acre. This implies that not only should the yield of "roots" be high, but that the percentage of dry matter of the individual roots be also high.

(2) It should be of good shape and form. The shape should be as near to globular as possible, at least symmetrical about the vertical axis, and should have a convex top so that water will easily run off. Types with a concave top are to be avoided, as water, settling there, sets up rot very rapidly. The crown should be as short as possible in the case of the turnip—the neck of the swede distinct, though short and thin. There should only be one neck or crown; multiple necks are most undesirable features as they entail loss in the upper part of the root.

(3) The tap-root should be slender and clothed with many fine short branch roots. The presence of more than one main root gives rise

Badly shaped turnip showing concave top

Swede showing multiple necks



Swede showing fanged roots

to a condition known as "fanged roots", which hinder cultivation, lay the roots open to attack to a greater extent below the ground by insect and fungoid pests, and materially reduce the amount of root available for feeding purposes. These types are usually of poor feeding quality.

(4) The turnip should be resistant to frost and to disease.

(5) The flesh should be firm, yet juicy, compact right to the core, and free from stringiness.

(6) In habit of growth the root should stand well above the ground without being unduly prolonged and so suffer from adverse weather conditions, and there should be a sufficiently abundant foliage to suppress the growth of weeds.

## Varieties of Turnips and Swedes: Classification and Notes.

As already indicated, turnips are divided into two main types, namely Whites and Yellows, by means of the colour of the flesh of the storage

organ. Each type is further divided into specific varieties by (*a*) colour above ground and (*b*) shape. Swedes are also classified according to the colour of the storage organ above ground, and the shape, but prominence is also given to the time of maturity.

The adoption of such a method of classification reduces to a large extent the immense number of names of varieties on the market, for study of these clearly shows that, from the morphological point of view, many sold under different names are synonymous types. It is unfortunate that only within the last two years has a systematic attempt been made to classify varieties, and naturally, since these are so numerous, such work must take a considerable time, with the result that information so far is incomplete. The classification given here is based mainly on external features. Such a method in itself is inadequate, although it is certainly useful in distinguishing types. Combined with this should be taken into consideration several other factors.

1. The amount of dry matter in the variety should be known, for varieties have different productive qualities. The results of experiments, as recorded in the *Journal of the Ministry of Agriculture*, March, 1920, pp. 1223 and 1224, carried out at Cockle Park, the Northumberland County Agricultural Experiment Station, illustrate this point well (see table on p. 82).

These figures show that: (*a*) the heaviest yields may not signify the largest amount of feeding value; dry matter content is the principal desideratum in this respect. This consideration is evident both when comparing turnips with swedes and when comparing one variety with another. (*b*) Varieties with the highest percentage dry matter may not be productive of the highest total amount of dry matter per acre, e.g. compare Champion and Up-to-date. This difference may however be reduced on submitting the roots to a feeding trial, when the greater amount of water in the crop per acre may react unfavourably on the feeding value—a question deserving of experimental evidence. Similar differences occur too in strains which are botanically similar, e.g. in the above case Caledonian is very similar to Darlington, and Purple Top Aberdeen and Favourite Purple Top are alike. This is only to be expected when analogies in the stock-breeding world are remembered.

2. The adaptability of a variety to particular types of soils and surroundings should be ascertained. Certain varieties, for example, may grow quite well on one type of soil, whilst they may be excelled by others on another type of soil. The adaptability seems to be influenced by habit of growth and innate qualities to suit itself to varying conditions of habitat. This is evident when the yields of different varieties, grown at various centres, are compared. Shown on p. 82 are the results of experiments on yields of the same varieties carried out by the West of Scotland Agricultural College in 1923 at Holmes Farm, Kilmarnock, and at the Wig-

VARIETIES OF SWEDES AND TURNIPS, 1915–8

Soft Turnips only two years' average (1915 and 1916)

Average Results per Acre for Four Years

| Variety. | Weight of Roots. | Percentage of Dry Matter. | Weight of Dry Matter. |
|---|---|---|---|
| | Tons. Cwt. | | Tons. |
| *Swedes.* | | | |
| Caledonian (Bronze Top) .. | 27 7¾ | 12·34 | 3·36 |
| Up-to-date (Bronze Top) .. | 26 19¼ | 11·83 | 3·17 |
| Improved (Bronze Top) .. | 26 8¼ | 12·03 | 3·16 |
| New Buffalo (Purple Top) .. | 25 11 | 12·02 | 3·06 |
| Darlington (Bronze Top) .. | 24 15 | 12·40 | 3·05 |
| Magnum Bonum (Purple Top) | 26 6 | 11·65 | 3·03 |
| Champion (Bronze Top) .. | 24 18¼ | 12·15 | 3·01 |
| Conqueror (Bronze Green Top) | 26 14½ | 11·97 | 2·94 |
| *Turnips.* | | | |
| Favourite Purple Top Aberdeen | 29 10 | 9·78 | 2·89 |
| Large Improved Green Top .. | 29 4½ | 9·35 | 2·70 |
| Purple Top Aberdeen .. .. | 26 4¼ | 10·01 | 2·63 |
| Green Top Aberdeen .. .. | 24 10½ | 10·50 | 2·59 |
| Perfection Green Top Aberdeen | 25 5 | 10·08 | 2·55 |
| *Soft Turnips* (1915 and 1916). | | | |
| Selected Fosterton .. .. | 25 17¾ | 9·15 | 2·54 |
| Purple Top Mammoth.. .. | 28 3½ | 8·23 | 2·30 |
| Pomeranian White Globe .. | 26 0½ | 8·32 | 2·19 |
| Centenary .. .. .. | 26 12 | 7·68 | 2·03 |
| Early Sheepfold .. .. .. | 21 6¼ | 8·92 | 1·89 |
| *Averages.* | | | |
| Swedes (8 varieties) .. .. | 26 2¾ | 12·05 | 3·10 |
| Turnips (5 varieties) .. .. | 26 19 | 9·95 | 2·67 |
| Soft Turnips (5 varieties) .. | 25 12 | 8·46 | 2·19 |

townshire Station respectively. The soil at the former is a deep loam, while at the latter it is a sandy loam.

| Variety. | Holmes Farm. | | Wigtownshire Station. | |
|---|---|---|---|---|
| | Tons. | Cwt. | Tons. | Cwt. |
| Knockdon .. .. | 34 | 10 | 31 | 12½ |
| Best of All .. .. | 21 | 11 | 24 | 18 |
| Elephant .. .. | 25 | 3 | 22 | 2 |
| Scotia .. .. | 24 | 12 | 27 | 3 |

3. The resistance of varieties to disease must be given consideration. Finger-and-toe disease is particularly widespread, and its infectious nature in addition to its destructive effects can be largely restrained by the choice of hardy varieties. Experiments carried out by the University College, Bangor, and reported in the *Journal of the Ministry of Agriculture*, July, 1922, pp. 362 to 368, are very instructive in this respect.

RESULTS WITH ENGLISH AND DANISH VARIETIES AT DINAS ON LIMED AND UNLIMED PLOTS

| Variety. | Limed Plots. | | | | | | | | Unlimed Plots. | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Number of Sound Roots. | Number of Bad Roots. | Number of Destroyed Roots. | Intensity of Attack, Maximum = 20. | Total Weight of Crop per Acre. | | Estimated Weight of Sound Roots when lifted per Acre. | | Number of Sound Roots. | Number of Bad Roots. | Number of Destroyed Roots. | Intensity of Attack, Maximum = 20. | Total Weight of Crop per Acre. | | Estimated Weight of Sound Roots when lifted per Acre. | |
| | | | | | Tons. | Cwt. | Tons. | Cwt. | | | | | Tons. | Cwt. | Tons. | Cwt. |
| Lord Derby . . | 70 | 162 | 4 | 6·9 | 13 | 0 | 3 | 18 | 32 | 199 | 4 | 8·8 | 14 | 14 | 2 | 0 |
| Danish Variety, 4 | 189 | 87 | 0 | 3·2 | 12 | 18 | 8 | 16 | 136 | 133 | 1 | 4·9 | 14 | 8 | 7 | 8 |
| Magnum Bonum | 95 | 170 | 2 | 6·3 | 14 | 2 | 5 | 2 | 48 | 204 | 4 | 8·2 | 14 | 14 | 2 | 16 |
| Pioneer . . . . | 90 | 159 | 1 | 6·4 | 13 | 4 | 4 | 16 | 34 | 210 | 5 | 8·8 | 13 | 14 | 1 | 18 |
| Danish Variety, 25 | 173 | 72 | 0 | 2·9 | 12 | 8 | 8 | 14 | 166 | 97 | 1 | 3·7 | 14 | 12 | 9 | 4 |
| Dreadnought . . | 95 | 142 | 2 | 6·1 | 13 | 6 | 5 | 6 | 51 | 178 | 5 | 7·9 | 13 | 14 | 3 | 0 |

Sound = not diseased and those so slightly attacked that disease would be removed in cleaning.
Bad = so seriously affected that no cleaning could remove whole of diseased tissue.
Destroyed = useless roots apparently destroyed by the disease.

This table shows that the Danish varieties were much more resistant than the others, and although their total yields were slightly less, those of the sound roots were much higher.

When submitted to a further test of keeping quality as afforded by clamping from the end of November till the middle of January, it was found that the percentage losses in weight for the different varieties through having to discard rotten roots was as follows: Lord Derby, 11·5; Magnum Bonum, 15·6; Pioneer, 20·4; Danish Variety, No. 4, 3·3; Danish Variety, No. 25, 2·7.

Resistance to disease does not necessarily imply low feeding value, for the results of dry matter analysis showed the following: Lord Derby, 8·3; Magnum Bonum, 9·5; Pioneer, 8·6; Dreadnought, 8·7; Danish Variety, No. 4, 10·0; Danish Variety, No. 25, 10·0.

Thus it appears that disease-resisting power is as essential in the classification of turnips as in potatoes.

A reliable scheme of classification can only be drawn up through

the efforts of the agricultural botanist, chemist, mycologist, and practical agriculturist working in harmony with each other. Independent action can lead but a short distance.

## A. WHITE TURNIPS

(*a*) *White above ground.*

1. White Globe: round to oval in shape but irregular; white skin above ground; rapid grower; usually matures about the end of September: heavy cropper; crowns often concave; very liable to rot, and should be consumed at maturity; a very old variety.
2. Pomeranian White Globe: similar to the White Globe, but more symmetrical in shape and more rounded; skin rather more transparent and leaves darker green; as heavy a cropper and a better keeper; introduced from Pomerania in 1830.

(*b*) *Red to purple above ground.*

3. Red Globe: globe-shaped with a tendency towards being cylindrical; red or crimson skin above ground; old leaves much divided; petioles and midribs reddish purple; very rapid grower, ready for consumption in September; a heavy cropper, but of a coarse inferior quality and softer than the White Globe; rots very readily; roots have a distinct tendency to become fanged; mainly suited for poor exposed soils.
4. Purple Top Mammoth: irregular in shape; usually semi-tankard; purple above ground with purple petioles; roots are often hollow and fanged, especially when large; very heavy cropper of inferior quality; liable to rot readily.

(*c*) *Green above ground.*

5. Green Top White: round in shape, pale green above ground; less rapid grower than other Whites, but firmer texture; much hardier, and of all the Whites can be kept longest in the season; a heavy cropper.

(*d*) *Mottled above ground.*

6. Greystone: globular to oblong in shape; colour of portion above ground purple and green, with purplish petioles; quality is poor, and altogether a variety which, once popular, has now lost favour.

## B. YELLOW TURNIPS

### Pale Yellow-fleshed

(*a*) *Green above ground.*

1. Sheepfold: round oblong in shape; green above ground; deep yellow below; a rapid grower; a heavy cropper, but apt to crack readily; soft and a poor keeper.

(*b*) *Russet green.*

2. Centenary: globe-shaped; green above ground with netted surface; heavy cropper, but very soft and only suitable for early use; introduced by Messrs. Sutton.

3. Fosterton Hybrid: oblong to globular in shape; grows well above ground; russety green above ground, with distinctly curled leaves; a heavy cropper and rapid grower, suitable for heavier types of soil; better keeper than Centenary and Sheepfold; very useful for sowing where early sown seed has failed; hybrid between White Turnip and Swede; introduced by Mr. R. Hutchieson, in Fifeshire.

#### Yellow-fleshed

(*a*) *Purple above ground.*

1. Purple Top Yellow: globular to oval in shape; purple above ground; heavy cropper and widely grown; rather subject to mildew in dry seasons. Stobo Blue is very similar, but has firmer flesh and is a better keeper.

(*b*) *Green above Ground.*

2. Aberdeen Green Top Yellow (Aberdeen Bullock): globe-shaped; green above ground; free grower; a heavy cropper of excellent quality; not so subject to mildew as Purple Top; stands winter well; very widely grown; numerous selections on the market under various names.
3. Aberdeen Green Top Golden Yellow: somewhat similar to the Bullock, but the root is more orange coloured, and is smaller; needs to be singled more narrowly to give as good a yield; originally put on the market by Mr. Hay, of Aberdeen, about 1900.
4. Green Top Yellow: tankard in shape; green above ground; little grown in Scotland, but fairly popular in England.

## C. SWEDES

### A. Early Types

(*a*) *Purple above ground.*

1. Best of All: globular to semi-tankard in shape; bright purple in colour; heavy cropper; very widely grown; softer flesh and not so resistant to disease as many others; keeps well when pitted.

   Great many selections have been made from this variety, which was introduced by Messrs. Dixon, Brown, & Tait about 1890.

   Similar types include: Magnum Bonum, Magnificent, Eclipse, Early Round, and Paragon.
2. Knockdon: semi-tankard in shape; pinkish purple colour; grows well out of the ground; has finer leaves than Best of All; suits heavier types of soil; heavy cropper; a selection from Best of All but now quite distinct.
3. Picton: nearly tankard in shape; pinkish purple in colour; somewhat similar to Knockdon, but has a particularly small amount of shaw; hardy, heavy cropper; raised from crossing Knockdon and Monarch; Superlative is very similar.

### B. Main Crop

(*a*) *Purple above ground.*

1. Enterkin: round in shape; russety purple, rough skin; heavy cropper and very resistant to frost; continues growing well during winter. It was originally raised in Aberdeenshire from Inverquhomery Swede by Mr. Charles Bruce.

2. Skirving: globular to oblong in shape; purple in colour; stands well out of the ground, has rather a long neck; good cropper, but now largely replaced by heavier yielders; introduced about 1837 by Skirving of Liverpool.

East Lothian and Bangholm are very similar. Strains of Bangholm are found to be fairly resistant to finger-and-toe disease. Springwood is very like Skirving, but rounder in shape and deeper purple in colour.

3. Monarch or Elephant: tankard in shape; deep purple in colour; stands high above the ground; a good cropper. Introduced by Messrs. Hurst & Son, London, about 1870. Crimson King is very similar.

(*b*) *Bronze above ground.*

4. X.L. All: round oval in shape; purplish bronze in colour; good cropper and keeper; well suited to conditions in the south-west of Scotland. Up-to-date, Model, and Ne Plus Ultra are similar.
5. Halewood: tankard in shape; bronze colour; free grower; good keeper. Scotia and Great Scot are similar. Incomparable, a mildew resister, is also of the same type.

(*c*) *Greenish bronze above ground.*

6. Conqueror: round in shape; greenish bronze colour; very hardy; an even and very good cropper. Caledonian, a similar type, is even a better cropper as a rule. Darlington and Supreme belong to the same type.

(*d*) *Green above ground.*

7. Green Top: round in shape; green in colour; inclined to be necky and woody; very hardy, but not so heavy a cropper as the others; is an excellent keeper and grown specially for late spring use; now largely being replaced by bronze and greenish bronze types; the commonest type is Kinaldie Green Top.

## Climate.

Climate determines the yield of the turnip crop more than any other factor, important as many of these are. The turnip is essentially suited to a temperate region, hence its wide popularity in Britain as compared with countries, within the same degrees of latitude, which are subject to greater extremes of heat and cold. Variations in the climate of Britain, even, largely account for the wide divergence of yield in various parts of the country.

The turnip always does best where neither extremes of drought nor heavy rainfall are experienced. Unlike the potato it does not require a great deal of sunshine, but makes rapid progress in warm, dull, moist weather. It grows well in the later part of summer and throughout the whole of autumn, even into early winter when the amount of sunshine is considerably reduced. For this reason it does particularly well in Scotland.

The annual rainfall and the distribution of the rain throughout the

year have a very important effect on the yield. This is only to be expected since the roots contain nearly 90 per cent of water. For the crop to produce a high yield it is essential that there be a continuous supply of soil water available to the plants throughout the whole of the growing season. In this respect it is similar to the mangel, but the latter does better under drier conditions than the former, the explanation of this being that the mangel is deeper rooted and has much less difficulty than the turnip in assimilating the necessary amount of water. In addition to the water in the mature roots a vast amount is transpired by the plants, and large quantities are also lost by evaporation from, and percolation through, the soil. It is found that the amount of water required by a plant, apart from evaporation and percolation, to produce 1 lb. of dry matter varies from 500 lb. in the case of wheat, to 800 lb. in the case of lucerne. Assuming turnips need as much as lucerne—they probably require far more since they show wilting in droughts much more quickly, but there is no exact information on the point—and considering that an average crop contains about $2\frac{1}{2}$ tons dry matter, 2000 tons of water will be required for the plants alone. 1 in. of rainfall represents 100 tons. Thus to give such a crop, a rainfall of 20 in. would be required. To this must be added the loss due to evaporation from and percolation through the soil as well as the amount passed out of the soil whilst there was no crop. The rainfall in a year supplying the amount of water contained in a good crop is thus insufficient to meet the needs of such a crop. The rainfall during the growing season is even more important than the annual one. The climate experienced along the east of Scotland, with a rainfall varying between 25 and 32 in. on an average, having no prolonged period of drought, produces the best crops in the country.

Rainfall and temperature are closely related factors in the determination of yield. Provided that moisture be continuously supplied, an increased average temperature under British conditions will increase the crop. This was plainly seen on the heavier types of soil in the west of Scotland during the dry summer of 1921.

Excessive rainfall is just as unfavourable to the growth of the turnip as an insufficient one, for unless the soil be very friable and open, water is retained in the upper layers and the lack of aeration stops growth. Where the rainfall is low and principally restricted to the autumn and winter months, the turnip is chiefly grown as a catch crop, as, for example, in the south-eastern counties.

The winter conditions are of importance in relation to the cost of the crop. If the weather be mild and free from prolonged frosts, the crop, especially the swede one, may be left growing without any protective covering, when it will make quite an appreciable increase. In favoured districts in the proximity of the sea, turnips are commonly

left growing during the winter months. On the other hand, if the conditions be severe, they must be stored or otherwise protected from the effects of heavy frosts, thus increasing the cost of production.

Elevation and exposure must also be considered. No hard and fast rule can be laid down with regard to elevation, for it is subservient to the degree of latitude of the district, and to its relationship to protection from other heights. Generally speaking, the best crops are raised at levels of less than 600 ft., though quite good results can be obtained under suitable conditions at greater heights. Care should be taken to select specially hardy varieties for elevated regions. Gradual slopes, in a southerly direction, give the best exposures. Northern exposures should be avoided on account of their liability to late frosts, which commonly give rise to "bolting". Land at the bottom of valleys has similar disadvantages.

Climate has a decided effect on the feeding value of the roots. The marked superiority of turnips and swedes grown along the east coast of Scotland has been for long recognized, particularly in Aberdeenshire, where cattle have been fattened on roots and straw alone. This is probably due, in part at least, to the roots of these districts having a higher dry-matter content, but there is unfortunately no exact information so far in Scotland to support this belief. It is possible that other factors may have an effect. In this connection, it is interesting to note that while the Magnum Bonum variety of swedes referred to on p. 82, showed an average of 11·65 per cent dry matter in the Cockle Park experiments, it yielded only 9·5 in the Welsh trials. The result, on account of soil, manurial, and cultural differences, is certainly not conclusive, but it is undoubtedly suggestive.

### Soils.

The turnip crop suits a wide range of soils, since the existence of White Turnips, Yellow Turnips, and swedes makes it adaptable to varying conditions. All of these, however, produce their maximum yields on the one type of soil, namely a good deep loam, resting on a fairly firm, naturally well-drained subsoil.

The swede does best on a deep well-drained loam. The soil must be in a good state of fertility in order to produce the highest yields, but quite good crops can be grown on a soil of this texture which has lost "heart", if it be well cultivated and liberally treated with organic and inorganic manures. The heavier types of land, such as clay loams and the lighter clays, sustain good crops provided that a suitably fine tilth be worked up prior to seeding. On such classes of soil, however, tillage operations are very costly, and there is always a danger that the soil will dry out unduly before sowing the seed, a common cause of failure in the turnip crop. Once the young plants are established they grow remark-

ably well and keep much freer from weeds than those on lighter soils.

The Yellow Turnip grows better than the swede on the lighter types of loam and on soils which are inclined to be late. The White Turnip is most adaptable to the lightest class of soils, narrow soils, and exposed regions.

Peaty soils are productive of good crops if they have been previously well drained and limed, but neglect of this procedure is sure to lead to failure.

Soils in a wet condition, and the heaviest types of clays, are totally unsuitable. Under wet conditions the leaves acquire a bluish purple tint and the crop makes no headway. Besides, excessive moisture sets up a sour (acid) condition in the soil which is specially favourable to the growth of the fungus causing finger-and-toe disease, one of the greatest scourges to which the crop is susceptible. Heavy soils lack the capability of being readily worked into a fine condition at seed-time, and, in addition to forming cracks on the surface in dry weather, are far too tenacious for the extension of the turnip's delicate young rootlets.

Turnip soil, in general, should contain a good stock of lime. The amount necessary is dependent on the class of soil, heavy soils requiring much more than lighter ones (see "Manuring", p. 97). Under average conditions it is desirable to have the equivalent of 0·5 per cent of lime in the soil (as CaO). Soils deficient in lime favour the onset of finger-and-toe disease, and they carry quick-growing smothering weeds, such as spurrey.

The nature of the soil exerts a great influence on the feeding quality of the roots. Varieties grown on well-manured loams in good heart give roots of much higher feeding value than the same varieties grown on poor soils.

### The Combined Effect of Soil, Climate, and Local Needs.

The nature of the soil as influenced by the underlying geological strata or flow of drift, combined with the average annual rainfall and temperature, explain the distribution of the crop throughout the country, as shown in Table IV, p. 75. It will be evident that the most important turnip-growing counties in England lie along part of a line which stretches from Devon and Dorset to Yorkshire, and then takes a north-western course into Northumberland and Cumberland. The centre of this line weakens slightly from Gloucester to Northampton, where branches are given off to Salop on the north-west and Norfolk on the north-east.

Starting in the deep red loams of the sandstones of the Old Red Sandstone, Permian, and Trias formations of Devon, it becomes very evident in the light soils of the Chalk in Hampshire. Then, after sending a branch to the more fertile red loams of the Red Sandstone and Lower Trias in Salop in the west and another to the light chalky soils of Norfolk in the east, it continues through the fertile Permian and Trias soils of Notting-

ham and Yorkshire into the more retentive loams of the Oolite in Lincoln and Yorkshire, as well as the lighter chalk soils of these counties. It next passes into the Mountain Limestone soils of Northumberland and the Permian and Triassic red loams of Cumberland.

In these counties there is a moderate rainfall, in the south-west averaging about 36 in. In Norfolk there is a reduction to approximately 22 in., whilst farther north the rainfall gradually increases to about 30 in. in Northumberland and over 40 in most parts of Cumberland. On the other hand, the midland counties and those of the south-east are drier than all of these except Norfolk. The average summer temperature varies in the opposite direction.

Combining soil and climatic conditions it is evident that where there is a fairly low rainfall and a soil retentive of moisture, a moderate rainfall and a rich soil, or a heavy rainfall and friable soil, temperature being suitable, the turnip crop is favoured. High summer temperatures and low rainfalls disfavour it on the lighter types of soil of the south-east. Its average is reduced to a minimum as a main crop in the Midlands and London basin, where the soils are heavy and crack readily. On the Chalk formations, which suffer greatly from drought, the turnip crop does not give heavy yields, and is chosen largely because it is one of the best available for the provision of a part of the succession of green material required for the feeding of sheep, which are so necessary to keep this land in a sufficiently fertile state for arable farming.

In Wales, the most important turnip-growing counties are on the Silurian and Ordovician formations, which have given rise to dark reddish brown loams of a very brashy nature, due to the many stones present. The Old Red Sandstone formation is famous for turnip growing in Brecknockshire and parts of Glamorgan, where the soil is a deep red loam. The rainfall in these Welsh counties runs about 35 in. per annum, and the average temperature is very similar to that of Northumberland. On these free-working, though stony, soils the amount of heat experienced in relation to the rainfall provides as heavy yields per acre as those of the east, but the roots do not possess so high a feeding value.

In Scotland, the turnip-growing counties lie along the east side. The soils in the north-east consist of drifts, overlying schists. Such soils are found in Aberdeen, Banff, and parts of Forfar and Perth. These are free working loams mainly. Where the soil overlies granite and other igneous rocks it is much heavier and turnips are less favoured. Parts of Forfar, Perth, and Berwick lie on the Old Red Sandstone, which bears deep red loams. Fife, on the other hand, is situated, apart from the volcanic areas and small patches of coal measures, on carboniferous limestone which gives rather heavier types of soil than the Old Red Sandstone, but yet fairly free working. A small part of Berwick is likewise placed on carboniferous limestone and still another portion of it is on the Silurian, which

bears soils similar to those of Wales on the same formation. The Silurian, in general, has given rise to good turnip soils throughout the southern uplands, but, whilst the contour of the land restrains arable farming greatly in the central parts of it, the area under cultivation is reduced in Wigtown, Kirkcudbright, and Dumfries by the dairy system of farming, which necessitates rather long rotations to provide sufficient pasture for the dairy cows. As has already been pointed out, the rainfall of the east coast of Scotland runs on an average from 24 to 32 in. per annum. At the same time the average annual temperature is somewhat similar to north-east England, although the summer temperature is slightly less. The combination of this amount of heat and rainfall gives the best crops in the country. The Silurian soils of the south-west are provided with rather less heat in proportion to their greater supply of rainfall and the crops are scarcely so heavy. The soils of the carboniferous system are rather heavy for turnip cultivation in Scotland, especially on the coal measure of the Midland Valley, but where the Old Red Sandstone crops out in these counties turnips are much in favour. The higher rainfall and lower temperature of the west, too, restrain the yield on the heavier soils.

Local needs influence the extent of the cultivation of the crop. In the vicinity of large towns, where there is a demand for turnips for culinary purposes, they are grown on heavy soils, otherwise unsuitable, as, for example, in the London and Lancashire districts. The high price received makes the venture profitable, whilst the cost of carriage eliminates competition from more favourable districts. Similarly, local needs influence the growth of some of the various varieties. Where provision must be made for the supply of green material to dairy stock during autumn, winter, and early spring, all three main types are sown, the proportion increasing from Whites to swedes. Only enough Whites are sown to allow of the Yellows and swedes coming to maturity, and wherever cabbages succeed, the latter are usually preferred to Whites for late autumn use. Green Top or Greenish Bronze and Bronze type of swedes are sown for longest keep. The needs of the season also determine the proportion of varieties. In late seasons large areas are sown with Yellows in order to ensure full crops, whilst the better-keeping swedes are preferred under ordinary circumstances.

### Place in Rotation.

Normally the turnip crop, when grown as a main crop as it usually is, is taken between two cereal crops. This is the case in the common Norfolk rotation and modifications thereof varying from five to eight years. The number of years between successive turnip crops naturally depends on the rotation. It is found that, unless the soil be specially rich in lime, it is unwise to take a second crop of turnips from the same

soil in a less interval of time than six years on account of the danger from finger-and-toe disease.

Sometimes the turnip crop is taken after lea, though this is not very common on account of the difficulty experienced in securing a suitably fine tilth. Besides, it is essentially a cleaning crop as well as a food crop, and land after a good lea is seldom very dirty. White crops, on the other hand, favour the growth of weeds, which can be controlled by introducing a cleaning crop.

Unlike the potato and mangel, it is very unusual for turnips to be grown on the same field for a number of years in succession. Indeed it is unsafe to have it follow any other crop belonging to the genus *Brassica*, such as cabbage, kales, &c., unless special precautions be taken. This is due to the liability of the crop to become infected with finger-and-toe disease, which attacks all cultivated forms of Crucifers in varying degree. The growing of cruciferous crops at too short intervals is most effective in spreading this disease. Cases are certainly known in which turnips have been grown on the same land for many years with success, but such land is dressed annually with lime at the rate of not less than 10 cwt. per acre.

There is no objection to taking a crop of turnips after another green crop which does not belong to the natural order *Cruciferæ*, such as potatoes or mangels. This is frequently done, especially when the land is very foul. A crop of potatoes is first taken and is succeeded in the following year by a crop of turnips. Such a practice allows of thorough cleaning operations for two seasons, and also gives the land an excellent opportunity of recuperating from the want of periodic stirring. This double green cropping principle may be reversed if desired, when the turnips will be taken before the potatoes, but more expense attends the cleaning operations in this case.

In the rotation adopted on the light down lands of Wiltshire and Hampshire, where the object is to provide a succession of green food for consumption on the land by sheep, the observation made above with regard to close cropping does not hold good. Turnips are taken three times in eight years, one crop being between two main white crops and the other two immediately following each other. In the latter instance late sown turnips follow a catch crop, and they in turn are followed by early turnips, which are eaten off in time for sowing wheat. This practice is successful on account of the chalky nature of this land.

Turnips, excluding swedes, are commonly grown as a catch crop, following early potatoes or peas, in the south-eastern counties of England.

### Preparatory Cultivation of the Land.

The cultivation of the land involves two distinct motives, namely the cleaning of the land and preparation of a suitable bed for the reception

of the fine seed. The cleaning must be thorough, because this is the only opportunity throughout the whole rotation that an opportunity is afforded of effectively clearing the land of weeds, which not only reduce the yield of the turnip crop very considerably, but also seriously interfere with the successful catch of grass and clover seeds. So far as the turnip crop itself is concerned, thorough eradication of quick-growing weeds is absolutely imperative. Poorly done work, carried out in a hasty, careless manner, is false economy, for weeds grow quickly and readily choke out the slower-growing young turnips, in addition to diminishing the yield by depriving the roots of much of the valuable manurial constituents of the soil.

The direction of the operations to fulfil these two objects demands a high degree of skill on the part of the person in charge of the tillage operations. This is due to the fact that while drying the soil well effectively kills out the weeds, lack of moisture will be equally detrimental to the procuring of a good braird of young turnips. It is impossible to lay down standard rules of cultivation to attain the ends mentioned, because soils vary very widely in the treatment which they require, not only between themselves but also between the tillages required on the same soil from year to year as a result of weather conditions. The principles of cultivation should be studied rather than the actual series of operations recommended in textbooks.

The following systems of cultivation are those ordinarily carried out under average conditions; they are, however, subject to wide variations according to local needs.

**Autumn Cultivation.**

Immediately after the cereal crop has been cleared, autumn cultivation of the land should be started in order to allow of the soil being subjected to the pulverizing action of frost and snow during the winter months.

In cases in which the land is comparatively clear of weeds it is unnecessary to adopt extensive cleaning operations. It is sufficient to fork out any odd patches of Couch Grass (*Triticum repens*), Pearl Grass (*Arrhenatherum avenaceum bulbosum*), and any other perennial weeds prior to ploughing the land as deeply as possible.

Such conditions are very uncommon, so much so that they may be neglected. Under ordinary circumstances, when the cereal crop has been removed by early autumn and the pressure of other work can possibly allow it, the stubbles should be cleared of weeds before the winter's ploughing is commenced. This procedure demands good weather. The common method is to plough the land shallowly to a depth of not more than 3 or 4 in., and cultivate it thoroughly with a spring broad-tined cultivator in two directions at right angles to each other. This operation

tears out Couch Grass and other weeds which spread from creeping stems or bulbs and brings them to the surface. At the same time it opens up the land sufficiently well to allow of the germination of the seeds of annual weeds. Toothed harrows are then drawn over the ground, thus disentangling the weeds from the soil. Exposure of the weeds to the drying influence of wind and air on the surface of the ground kills them, and they may then be gathered off by chain harrows and burned. As an alternative to the above method of shallow ploughing, the advent of the tractor has made possible the breaking up of the land by disc harrows, which can be followed in turn, as already described, by the cultivator and the harrows. In many cases the soil is first of all torn up by steam cultivating plant. Light soils can be worked in this way by horse-drawn cultivators. The land is then ploughed as deeply as the soil will admit and left in this condition during the winter.

In the dry counties of the south of England, particularly on the heavy types of soil, the land is laid up in ridges, locally termed " baulks ", immediately after the final deep ploughing. The baulks are made in a direction at right angles to the furrow slices. During winter, whenever dry spells of weather allow it, the baulks are split, and it is found that the oftener this is done the better is the condition of the land in the spring. This procedure prevents washing of the surface of the soil during winter, and therefore keeps the particles from forming into cloddy masses in wet weather. It also very materially aids in the conservation of rainfall, which is mostly confined to the winter months, and increases the area of soil laid open to the winter's effective weathering agents.

These autumn cleaning operations demand good weather. Inclement conditions, in addition to pressure of work in other directions, as, for example, the sowing of wheat, harvesting of potatoes, mangels, and turnips, often prevent this work being carried out. A different procedure must consequently be adopted.

Under these circumstances the land should be ploughed as deeply as possible prior to the onset of winter frosts. Ploughing should not be carried out when the soil is in a wet condition, especially on the heavier types of soils. The consolidation of the furrow slices in such a case gives rise to hard sticky lumps, which, later, cannot be broken down, and it is impossible to work up a suitably fine tilth. This ploughing should be the deepest in the whole rotation. It is impossible to state any particular depth on account of the great variation in soils, but it should be as great as possible without turning up any subsoil, which should on no account be brought to the surface. However, it is very advisable to have a subsoil attachment carried on the plough which can effectively stir up the top few inches of the subsoil. For this purpose, and for the procuring of a good furrow, a modern digging plough with a subsoil attachment serves excellently. It is not

desirable to have the furrow slices set up with a sharp crest, as this results in the connection between the lower edge of the furrow slice and the subsoil being reduced to a minimum, thereby interfering with the natural rise of water from the water-table level and causing the surface soil to suffer from lack of moisture. Deep ploughing cannot be too highly recommended. It destroys any pan that may be present, increases the range for the plant roots, makes more materials in the soil available for the plants, and vastly encourages the work of bacteria and weathering agents by more thorough aeration.

In some cases, especially in dry regions, farmyard manure is applied to the soil before the autumn ploughing. Deep ploughing in this instance is apt to bury the manure, but this drawback can be easily overcome by first ploughing in the manure lightly and then ploughing the soil to the desired depth, when the manure will be sandwiched between the furrow slices at a depth within the range of the roots.

After this ploughing the land is allowed to lie open to the effects of frost and snow during the winter months, when the alternate expansion and contraction of spaces between the soil particles ultimately leaves a very fine friable surface, which can be fairly easily worked into a mealy condition in spring-time.

On some heavy soils it has for long been the custom to plough two or three times, successive ploughings being at right angles to each other. This system should only be adopted in extreme circumstances, and when adopted should be carried out before the end of the frost season.

**Spring Cultivation.**

It was formerly a common habit in working turnip land in spring to prelude all cultivation by ploughing the land at this time in a direction at right angles to that at which it had been ploughed in the autumn, even when these cultivations had to be delayed till May. The practice is still too common. It cannot be recommended, because the fine mould produced during winter-time is turned into the body of the soil, and the soil is so much opened up at its lower depths that it suffers from lack of moisture later in the season. An experiment carried out in Invernesshire in 1914 by the North of Scotland Agricultural College and reported in the *Scottish Journal of Agriculture*, June, 1920, p. 28, illustrates the evil effects of cross-ploughing on the yield of turnips per acre.

| | Cross-ploughing. | | Cultivations only. | |
|---|---|---|---|---|
| | Tons. | Cwt. | Tons. | Cwt. |
| Yield per acre .. .. | 7 | 16 | 11 | 8 |

Cross-ploughing should only be resorted to in the case of fairly heavy land, which has been under grass for a long period prior to cropping.

Alternate cultivation and harrowing cannot deal effectively with the clods of earth and old matted grass, and so reliance must be placed on use of the plough. To obviate the evil of opening up the lower layers of the soil unduly by this measure, it is advisable to follow it by either furrow pressing or heavy rolling with a Cambridge roller.

Ordinarily in spring, after the work of putting in cereal crops, potatoes, and mangels has been completed, the land is alternately stirred up with the spring-tined cultivator and harrow, in directions at right angles or otherwise to each other. The number of times each implement is used varies with the condition of the soil. Twice is often sufficient. Perennial weeds are thereby brought to the surface and killed by drying, whilst annual weed seeds are made to germinate and are afterwards killed. These weeds, both annual and perennial, should then be gathered from the surface, after having been drawn into masses by a chain or parmiter harrow. For the lighter classes of soils and loams the work of tearing out weeds, especially underground creepers, and of reducing the earth to a fine state can be greatly facilitated by replacing the cultivator by the spring-toothed harrow.

In the course of these operations the land is reduced to a very fine condition, and while the lower layers are being consolidated by the constant trampling and sinking of the overlying soil, the top few inches are worked into a mulch. This allows of water being brought to the level of the base of the mulch, while the mulch prevents its evaporation from the surface. The land is now ready for manuring and the sowing of seed.

On the lighter classes of soil it is advisable to have the cleaning and pulverizing operations completed a week or so before it is desired to sow the seed. This allows the soil to consolidate slightly so that there is little fear of failure due to lack of moisture. After this period of rest and immediately before drilling, the land is given a stroke of the harrows to kill off any weeds which have germinated. Heavy types of soil present a particular difficulty in regard to spring cultivation, in that the top layers of the soil are very apt to become unduly dry, thereby causing the seed to give faulty germination. To overcome this difficulty it is always advisable to tackle the area in portions, so that the whole of the cleaning and tillage operations of each portion can be completed in a couple of days or so. Overworking of the soil should be carefully guarded against, as it not only dries out the soil too much, but it is also liable to favour finger-and-toe disease.

The preparation of the soils of the Chalk formations of Wiltshire takes much less work than that described above. This land is practically always under either one crop or another and seldom gets foul. The frequent tillage thus makes it very friable. When it is intended to sow turnips, soil is usually only ploughed and harrowed prior to seeding.

## Manuring.

A good yield of turnips can only be expected, even on the most favourable soils, when the crop has been supplied with a properly balanced mixture of manures. This should provide available phosphate, potash, and nitrogen. In addition, if the soil be lacking in lime, the application of a medium dressing reacts favourably on the yield.

The turnip crop is particularly dependent on a supply of phosphates which stimulates root development and rapid growth. Potash is also very necessary, though to a lesser extent than phosphate. It promotes the formation of carbohydrates and considerably restrains disease. The supply of nitrogen on the other hand can be curtailed to a greater extent than in the case of cereals and of other root crops. Small dressings are found to give as good results as large ones, and the roots keep much better. The lesser need for nitrogenous manures is due to the fact that nitrification is actively encouraged by the cultivation of the ground during a large part of the growing season.

Chemical analysis of the turnip crop gives no indication of its manurial requirements. Such shows that a crop of 17 tons takes from the soil approximately 110 lb. of nitrogen, 149 lb. of potash, and 72 lb. of phosphate.[1] These quantities would be supplied by $5\frac{1}{2}$ cwt. sulphate of ammonia, $12\frac{1}{2}$ cwt. kainit, and $2\frac{1}{2}$ cwt. superphosphate. Results of experiments on the manuring of turnips show that these quantities are quite unrepresentative of the needs of the crop; the amount of phosphate is totally inadequate, while the amounts of potash and nitrogen are excessive. This is due on the one hand to nature's agents, and on the other to the assimilating power of the plant for the various manurial requirements. The manures can either be supplied in the form of farmyard manure supplemented by artificials or by artificials alone.

**Farmyard Manure + Artificials.**—As for other root crops the basis of manuring should always be, when practicable, a dressing of farmyard manure. This manure not only improves the yield of the root crop, but its incorporation with the soil has a far-reaching effect on the succeeding cereal and grass crops. Indeed, a good catch of grass and clover seed, in particular clovers and finest grasses, is very much dependent on the application of farmyard manure to the root crop. Farmyard manure, in so far as it is beneficial to all these crops, acts not only as a source of food material, but plays an even more important part in regulating the physical and biological conditions of the soil. It aerates the soil and retains in its upper regions a constant supply of water without rendering the ground water-logged. Turnips manured in part with dung usually start growth and resist drought much better than those manured with artificials alone.

[1] *Chemistry of the Farm*, R. Warrington.

Land affected with finger-and-toe disease, however, should not receive an application of dung, nor should farmyard manure which has been made from stock consuming turnips affected with finger-and-toe be applied. Such soils require special treatment from the manurial point of view, and will be considered after the ordinary conditions have been dealt with.

The best method of applying farmyard manure to the turnip crop is a point which has engaged the close attention of agriculturists for a long time, and opinions are not yet by any means unanimous. Generally speaking, on dry open soils and on soils in dry regions it is better to apply well-rotted dung to the stubbles before ploughing in autumn, and plough it in. In the case of land, too, which may prove susceptible to finger-and-toe disease, it is also advisable to plough it in. On the other hand, on heavy soils and in soils in wet regions better results are obtained when the dung is put in the ridges in a fresh state. This has been shown in the west of Scotland on several occasions. The following table shows the result of experiments, carried out over three seasons, to ascertain the effect of the time of application. The results each year were in accordance with the averages shown.

| Time and Manner of Application. | Yield | | |
|---|---|---|---|
| | Tons. | Cwt. | Qr. |
| 20 tons dung applied to stubble and immediately ploughed in .. .. .. .. .. | 19 | 0 | 0 |
| 20 tons fresh dung applied in drills in spring .. | 22 | 2 | 3 |
| Residue of 20 tons fresh dung rotted in a heap in the field and applied in drills in spring .. | 20 | 1 | 0 |

Whilst these may be the ideals, they are difficult to carry into practice on account of the need for distribution of work throughout the year. This is particularly so with regard to the application of dung in the ridges, when the whole of the work of applying manure needs to be carried out at the busiest time of the year, namely seed-time. The future operations in this respect can be greatly facilitated by carting manure not required for other purposes to the fields intended for cropping with turnips, where it can be put into well-compacted heaps. This work can be profitably performed during spells of frost. Even this is occasionally difficult of execution, and accordingly the practice to be adopted resolves itself into a matter of convenience, commensurate with greatest possible success.

When it is desired to apply the manure to the stubble and have it ploughed in, it is a good practice to draw the field into squares by means of lines made at right angles to each other by the plough. In this way the manure can be more evenly distributed. The dung may be scattered direct from the cart or left in small heaps in the field and later spread.

If the latter practice be adopted care should be taken to have the manure spread immediately; otherwise growth of the crop will be uneven, due to the washing out of the soluble material in the dung, while it is lying in the heaps. The manure should then be ploughed in immediately to prevent loss. A difficulty arises here in that the need for deep ploughing may cause the dung to be buried. This can be got over, as has already been mentioned, by first of all ploughing in the dung lightly and then ploughing the land to the desired depth immediately afterwards.

When it is desired to put dung in the ridges, drills are opened by means of the double mould-board plough or double driller. The carts of manure are then drawn along the drills and the manure thrown into them in small heaps, one drill being taken at a time. The manure is later spread by graip (hand-fork), artificial manures sown on the top, and the drills covered in by the double board plough in the ordinary manner.

*Rate of Application.*—It is always better to apply a medium dressing of from 12 to 15 tons, supplemented by suitable artificial manures, than to supply heavy dressings. Under most conditions 12 to 15 tons is ample, but if the soil is very badly out of condition a larger dressing may be given with advantage.

Farmyard manure alone used within the limits of economy does not supply all the material requirements of the turnip crop. When used in large quantities, however, fairly heavy yields can be obtained, but the roots find more difficulty in starting away well and suffer more from disease. The turnip is especially dependent on a supply of phosphate which favours a rapid growth, but it is much less dependent on nitrogenous manures. Farmyard manure is relatively poor in phosphates and rich in nitrogen, so that applied alone it gives a badly balanced manure.

The following results of experiments carried out by the West of Scotland Agricultural College point to this conclusion.

| Manures. | Increase over Unmanured Plot per Acre. | | |
|---|---|---|---|
| | Tons. | Cwt. | Qr. |
| 20 tons farmyard manure .. .. .. | 7 | 0 | 0 |
| 10 tons farmyard manure .. .. .. | 5 | 12 | 2 |
| 10 tons farmyard manure and artificials .. | 8 | 0 | 0 |

The artificials consisted of 4 cwt. superphosphate and ½ cwt. sulphate of ammonia.

The scarcity of farmyard manure and the high cost of its application do not warrant heavy doses. Besides, heavy dressings of dung, especially when applied alone, produce roots very susceptible to attacks from the turnip fly, and they are usually softer and of poorer keeping quality than those raised from the combined use of artificials and dung.

**Artificial Manures.**—The best results are obtained from a mixture containing 22 per cent phosphates, 5 per cent potash, and 2 per cent nitrogen. The proportions may be varied according to soil conditions.

Phosphates should preferably be applied as a combination of both soluble and insoluble forms. The soluble phosphates provide a readily available supply for the crop during its early stages of growth, whilst the insoluble phosphates are usually cheap, restrain acid conditions, and provide a sufficiently continuous supply throughout the growing season if they are finely ground. This combination can be arranged by using superphosphate as the source of soluble phosphates, and basic slag, raw mineral phosphate, or steamed bone flour as the basis of the insoluble material. Superphosphate is an acid manure and liable to favour finger-and-toe disease, but the small amount of it used in mixtures such as mentioned, avoids any tendency in this respect. In choosing insoluble phosphates the state of fineness of grinding is the most important point to consider. Basic slag should be guaranteed to have at least 80 per cent of it able to pass through a riddle with 100 meshes to the linear inch, and raw mineral phosphate should preferably be capable of passing through a riddle with 120 meshes to the linear inch. Equivalent amounts of basic slag and raw mineral phosphate can replace each other on the heavier soils, while steamed bone flour is to be favoured for light soils. Bone meal may take the place of either steamed bone flour or basic slag as a source of phosphate, but it is usually dearer, and is no more efficient than either of these. Besides, while its nitrogen constituent is of very little immediate value, the phosphate in it does not store up any more fertility in the soil for future use than the other cheaper kinds of phosphate. The choice of phosphates is largely a question of rate of action and price per unit.

Potash should be applied under all circumstances except when the soil is a heavy one which does not respond to additions of this ingredient. It increases the resistance of the roots to diseases such as mildew, and materially increases the crop, especially in dry seasons. The particular form which the potash should take should be the cheapest selection from kainit, potash salts, or muriate of potash. This is usually kainit or potash salts.

The nitrogenous manure used should be readily available for the crop, and can be chosen from any of the common inorganic ones—sulphate of ammonia, nitrate of soda, nitrate of lime, or nitrolim. With the exception of nitrate of soda and nitrate of lime these should be wholly applied along with the other manures at the time of sowing the seed. Nitrate of soda or nitrate of lime should be applied as a top dressing after singling the plant. If the soil is likely to be subject to finger-and-toe disease only neutral manures should be used; sulphate of ammonia in particular should be avoided.

The rate of application of the artificials varies with conditions pre-

vailing in the district. Where the climate allows of a crop of at least 20 tons per acre, the following equivalents of manurial dressings can be depended upon to give quite good results when used along with 12 tons of farmyard manure.

150 lb. phosphates stated as tricalcic phosphate [$Ca_3(PO_4)_2$].
28 lb. potash stated as potash ($K_2O$).
15 lb. nitrogen stated as nitrogen (N).

Mixtures containing approximately these amounts are as follows:

| | | Cwt. |
|---|---|---|
| A. | Superphosphate, 30 per cent | 2 |
| | Steamed bone flour | $1\frac{1}{2}$ |
| | Kainit | 2 |
| | or Potash manure salts, 30 per cent | 1 |
| | Sulphate of ammonia | $\frac{3}{4}$ |

These ingredients can be mixed together and sown conveniently. Sulphate of ammonia may be replaced by 1 cwt. nitrate of soda, which would be applied *only* as a top dressing.

| | | Cwt. |
|---|---|---|
| B. | Superphosphate, 30 per cent | 2 |
| | Raw mineral phosphate, 60 per cent | $1\frac{1}{2}$ |
| | Kainit | 2 |
| | or Potash salts, 30 per cent | 1 |
| | Sulphate of ammonia | $\frac{3}{4}$ |

These can also be mixed and sown together.

| | | Cwt. |
|---|---|---|
| C. | Basic slag, 20 per cent | $4\frac{1}{2}$ |
| | Superphosphate, 30 per cent | 2 |
| | Kainit | 2 |
| | or Potash salts | 1 |
| | Sulphate of ammonia | $\frac{3}{4}$ |

The basic slag must be sown alone. The other manures may be mixed.

Under less favourable turnip-growing conditions, smaller applications of manure may prove more economical.

Lime, at the rate of 1 ton per acre, can usually be applied profitably to the turnip crop.

**Manuring with Artificial Manures Alone.**—On soils affected with finger-and-toe disease, the use of farmyard manure should be avoided as it favours the growth of the causal fungus, and where farmyard manure is scarce reliance must be placed on artificials alone. Quite good crops can be grown by this method, but it must be remembered that this observation applies mainly to the turnips, as the succeed-

ing crops, especially grass and clover, greatly benefit from the residual value of dung applied to the root crop.

The same manures as referred to above should be employed, but the amount per acre should be doubled. Superphosphate and sulphate of ammonia, however, should be avoided as far as possible when an attack of finger-and-toe is feared, but it is always useful to include a small dressing of superphosphate to bring the crop to the singling stage a little more quickly. A suitable dressing would be: 8 cwt. basic slag (30 per cent), 2 cwt. superphosphate (30 per cent), 4 cwt. kainit, $\frac{1}{2}$ cwt. nitrate of soda or $\frac{3}{4}$ cwt. nitrolim. This should be applied at the time of sowing, and a top dressing of $\frac{3}{4}$ cwt. nitrate of soda given after singling the crop. It is better to sow about half of the nitrate of soda, when used, along with the other manures at the time of seeding and top dress later on with the remainder. This gives better results than applying the nitrate of soda wholly as a top dressing. Neutral sulphate of ammonia, $\frac{1}{2}$ cwt., may be used in place of part of the nitrate of soda at seeding-time.

**Application of Lime.**—In addition to the dressings of artificials in the case of finger-and-toe land, the soil should be given an application of lime at the rate of 2 tons of quicklime per acre, or its equivalent in the form of ground limestone or waste lime. If 2 tons cannot be afforded at least 1 ton should be applied. This lime should be applied as soon after ploughing as possible, and carefully and thoroughly worked into the soil, or, alternatively, applied in the same way as dung on the flat, by ploughing it in with a shallow furrow at first and then more deeply. Lime materially decreases the susceptibility to disease and increases the crop. The table opposite gives the results of an experiment carried out in Dumbartonshire under the auspices of the West of Scotland Agricultural College, showing that lime increases the yield on soils lacking in this constituent and pointing out the usefulness of waste lime in this direction.

The table shows that lime considerably increases the yield. Its effect is probably an indirect one. It also shows that waste lime is quite effective. The superiority of waste lime in this case was considered most likely due to its being applied in the carbonate form, since the soil is a light loam. It is also worthy of note that the effect of the lime is most accentuated in the case of the plots receiving superphosphate, which is an acid manure. The basic manures, on the other hand, show a less, though still distinct need for the addition of lime.

Even when dung is used, as under ordinary conditions, it is advisable to give a dressing of lime unless the soil be of a calcareous nature. Heavier dressings are required on stiff soils than on light ones, as they considerably improve the tilth. In the former case it is better to use lime shells or ground lime, while in the latter ground limestone usually answers best.

| Lime Treatment. | Manures. 10 tons Farmyard Manure, $1\frac{1}{2}$ cwt. Potash Salts, 1 cwt. Sulphate of Ammonia. | | | | | |
|---|---|---|---|---|---|---|
| | 6 cwt. Superphosphate, 30 per cent. | | 2 cwt. Superphosphate, 6 cwt. Basic Slag, 20 per cent. | | 2 cwt. Superphosphate, 2 cwt. Steamed Bone Flour. | |
| | Tons. | Cwt. | Tons. | Cwt. | Tons. | Cwt. |
| No lime .. .. .. | 26 | $14\frac{3}{4}$ | 27 | $2\frac{1}{2}$ | 26 | 7 |
| 23 cwt. ground lime .. .. | 30 | $4\frac{1}{2}$ | 29 | $16\frac{3}{4}$ | 29 | $1\frac{1}{4}$ |
| 40 cwt. waste lime, supplying same amount of lime (CaO) as above .. .. .. | 34 | 17 | 29 | 8 | 29 | $16\frac{1}{4}$ |
| Difference due to ground lime | 3 | $9\frac{3}{4}$ | 2 | $14\frac{1}{4}$ | 2 | $14\frac{1}{4}$ |
| Difference due to waste lime | 8 | $2\frac{1}{4}$ | 2 | 5 | 3 | 9 |

**Effect of Manuring on Keeping and Feeding Quality of Roots.**—Though farmyard manure used alone in heavy doses may produce large crops, the roots tend to have an increased water content; they are consequently soft and of poor feeding value. They do not keep as well as turnips grown with a well-balanced manure. On the other hand, when farmyard manure is used in moderate quantities—10 to 12 tons per acre—in conjunction with artificials, the roots keep as well as those grown with artificial manures alone and their feeding quality is as high.

When basic slag or raw mineral phosphate is used as part of the source of phosphate, especially if no farmyard manure be applied, the keeping quality of the root is considerably improved and the feeding quality slightly so. Dressings of lime act in the same direction.

Kainit, potash salts, and muriate of potash are equally efficacious as sources of potash. The use of potash improves the keeping qualities of the crop.

The various nitrogenous manures are of equal value, considered from the point of view of their nitrogen content, for the production of feeding and keeping quality, provided that no finger-and-toe disease exists. It has been previously pointed out that sulphate of ammonia favours this. Excessive doses of nitrogenous manures produce watery roots of low feeding and poor keeping quality.

**Application of the Artificial Manures.**—Care should be taken not to mix manures containing free lime with those containing ammonium compounds; superphosphate, too, should not be mixed with nitrate of soda unless the mixture is to be sown at once. A drier,

such as steamed bone flour, should always be included in the mixtures.

When the seed is sown on the flat, the artificial manures are usually sown at the same time from a distributor, mounted in connection with the seed box, which places the manure in front of, and at a slightly lower level than the seed. When sown in ridges they are usually cast in previously opened drills, on the top of the farmyard manure, if it has been applied at this stage. The drills are then split back over the manure, which is thereby deposited under the roots of the plants. Sowing in the drills can be carried out by hand or from a machine set to distribute the manure along the rows. When no farmyard manure is used the double driller and manure sower proves very successful.

As an alternative to this method, when no farmyard manure has been applied, the manures may be broadcast before drilling, and the land subsequently drilled in the ordinary way. It is found that the manure is fairly well spread throughout the heart of the ridges by adopting this method. Basic slag should be sown alone from a distributor, either in the drills or broadcast before drilling the land. None of the artificial manures should be worked into the land during cultivation. Nitrate of soda applied as a top dressing is either sown by hand along the rows or a small amount of it is carefully placed at the root of each plant.

### Sowing the Seed.

The method adopted of sowing seed varies with the nature of the climate. There are two main methods, namely sowing on the flat and sowing on the ridge.

The former is practised in the south and midlands of England, and the latter in the north of England and throughout Scotland generally. There is no sharp line separating the area devoted to sowing on the flat from that of sowing on the ridge. The direction of the division is not strictly east and west; the ridge system prevails farther south on the western side because of the higher rainfall. The division may be said to start slightly south of the Trent and take a south-west course. Local experience largely determines the system adopted along the borders of this line. When grown as a catch crop the seed is broadcast.

**Sowing on the Flat.**—After the tillage operations described above have been carried out, the land is rolled if the surface soil be at all loose. On the other hand, if the surface soil be already fairly firm there is no need for rolling. The seed and artificial manures are then sown simultaneously from a seed drill with five coulters. The manure is deposited at a slightly greater depth than the seed and immediately in front of it. Sometimes the manures are broadcast and the seed sown separately.

The distance between the drills varies according to local custom, from 15 to 24 in., but the commonest distances are from 20 to 22 in., which allow of sufficient room for inter-drill cultivation by horses. On the light

chalky soils, both turnips and swedes are often drilled in rows 16 to 18 in. apart. This allows the leaves to meet in the drills more rapidly and thereby reduces evaporation, but the roots never attain the size of those grown with wider drills. On heavier and deeper soils, capable of growing good crops, 22 in. is a desirable width.

Although this practice is not in vogue in Scotland, it is probable that it would meet with success on the light types of soils along the coast, which often suffer from drought.

**Sowing on the Ridge.**—In this system the land is thrown up into raised ridges or drills by means of the double mould-board plough. This plough throws up on each side of it half a drill, which is completed by the return of the plough in the other direction. The drills should be drawn along the greatest slope; when made across the slope the turnips in wet districts are more liable to suffer from disease. The width of drills varies from 24 to 30 in., but the best results for swedes and Yellows are usually obtained from a drill of 27 in. This allows ample room for drill cultivation and for the covering in of manure. In the case of the White Turnips, which are quicker growing, a width of 24 in. is sufficient.

In carrying out the process of sowing on the ridge it is usual to drill the land in this manner first of all and spread the farmyard manure along the bottom of the drills. The artificial manures are then sown on the top of the dung, and the original drills split over by the double mould-board plough cutting through the centre of the ridges. When no farmyard manure is applied at this stage, the opening drills should be drawn more shallowly and the closing ones made of the usual depth. In this way the artificial manures are not buried too far out of reach of the plant roots as they otherwise would be. As alternatives to making shallow drills, which is a difficult operation to perform, the first drawn drills can be lightly harrowed down by means of the parmiter harrow or the artificials may be broadcasted before drilling, when the pushing action of the double mould-board plough places the manure within the ridge. Just as much of the land should be drilled in a day as will allow of being sown that day. Drilling followed by immediate sowing ensures a far better braird of swedes or turnips than sowing on ridges laid up a day or so previously. On light soils the same effect is sometimes obtained by setting up the drills a fortnight before sowing. The work of opening drills is greatly accelerated by the use of the combined double driller and manure sower, especially when no farmyard manure is being put in the drills. If it be desired to put in dung, the manure-sowing part of the machine will not be utilized.

On heavy types of soil, when it is difficult to get a fine tilth, the double mould-board plough can be substituted by the swing plough. Whereas the former merely rearranges the level of the soil by pushing it into

ridges, the latter raises the finest particles of soil to the ridge and makes a far better bed for the tiny seed. This system, however, not only involves twice the amount of work, since only a single half ridge is made each time, but it also demands a much higher degree of skill on the part of the operator; still, its success justifies the trouble expended upon it.

After the drills are finally made the seed is sown from a turnip drill which sows two drills at a time. This is provided with concave rollers which ride over the ridges, and the seed is deposited on the top of the drills in little seams made by coulters or discs. The depth of sowing should be about half an inch. Very deep sowing cannot be recommended as it causes faulty germination unless the soil be a very open one. Some drills are provided with small rollers which follow the coulters. These have the advantage of compressing the surface and hastening germination and growth by bringing soil water to the top of the ridge. On very light soils and during a long spell of dry weather it is advisable to roll the ridge with the smooth roller or the spiked drill roller before sowing the seed to encourage moisture to come to the surface.

**Sowing on Raised Ridges and on Flat Compared.**—In Scotland and the north of England where the climate is wetter than in the south of England, surface water is easily drained off along the bottom of the drills, leaving beneath the plants on the ridge a well aerated and moist layer of soil, favourable for the extension of roots and the restriction of soil fungi. The raising of the finest particles of the soil into ridges immediately below the roots provides a greater concentration of the reserves of soil nutrients which have been made available for plant assimilation by weathering during the winter and spring. The greater surface exposed, too, allows this process to be carried on more efficiently. Farmyard manure which has been made in the spring and late winter can be used in the drills, and so wastage due to keeping over summer is avoided. Rapid-growing weeds can be more easily kept down before the young turnips are ready for singling, and the process of singling is more easily carried out.

On the other hand, sowing on the flat reduces the evaporation of moisture to a minimum, which is so desirable in the south, for whilst the pressure of the upper surface on the lower layers allows soil water to come within reach of the plant roots, the fine mulch prevents this water coming to the surface to be easily evaporated. The smaller area of soil exposed under this system also reduces the total evaporation. Further, the necessary ploughing in of the farmyard manure in the autumn very materially helps to retain moisture. The great disadvantage of the system is that the position of the rows where the seeds have been sown is not clearly marked, and it is therefore necessary to wait till after the crop has brairded before attempting inter-cultivation of any kind.

**Time of Sowing.**—The order of sowing of turnips and swedes

varies inversely as their rate of maturing, swedes being sown first and White Turnips last. In Scotland and in the north of England, swedes are usually sown at any time from the last week of April till the 25th of May. They should if possible be sown by the second week of May. Early sowing (beginning of May) greatly increases the yield. However, the work should be delayed till heavy morning frosts have ceased, as these may later cause many of the plants to bolt. If the weather becomes so unfavourable that the whole of the swedes are not sown by the time indicated, it is better to replace them by Yellow Turnips, as a greater amount of dry matter per acre can thus be obtained. Late-sown swedes produce much foliage and very little root. Yellows are usually sown from the middle of May till the first week of June, whilst Whites can alone be relied on when drilled in the middle of June. Yellow and White Turnips, when early sown, are especially liable to bolt and to suffer from mildew.

In the south and midlands of England turnip sowing is about a month later than Scotland for all varieties. It is found that not only do early sown roots bolt readily but they also become easily affected with mildew, particularly in seasons in which their growth has been stopped by drought after making rapid progress. Swedes are usually sown between the last week of May and the end of June, but they may be drilled up till the middle of July. Early sown turnips are sown in June and July, and late sown ones in July and August. The latest sown turnips stand the winter quite well, and although the roots are small, their foliage (in flower in spring) considerably augments their value for folding breeding ewes after lambing in spring. When grown as a catch crop they may be broadcast till the beginning of September, but in this case they are only sown with the object of producing foliage.

**The Choice, Treatment, and Amount of Seed to Sow.**—Varieties should be chosen firstly to suit the soil and climatic conditions, and secondly the purpose for which grown, e.g. Whites for early consumption and Green Top Swedes for late spring use. Care should be taken to select varieties which, in addition to being good resisters of disease, are known to produce the greatest amount of dry matter per acre on that particular type of soil.

As a preventive to attack of the seedlings by the Turnip Fly, it is very useful to steep the seed in paraffin or turpentine for two hours before sowing. It should then be dried in the sun or otherwise before being used.

The size of the seed appears to have an influence on the resulting crop. Large sized seed of any variety gives stronger and bigger plants than smaller seed of the same variety, but this condition does not hold good when comparing different varieties. The seed, too, should be new and of high germinating capacity.

The amount of seed to be used varies with (*a*) variety, (*b*) time of

sowing, (*c*) germinating capacity, and (*d*) condition of the land. (*a*) Swede seed is bigger than common turnip seed and thus requires rather more per acre to provide the same number of plants. (*b*) Early sown seed requires to be drilled more thickly than late sown seed—the more advanced the season the smaller the amount of seed required. (*c*) Seed of low germinating capacity and old seed, which is slow in germinating, must be sown more thickly. (*d*) When the tilth is very fine less seed is required than otherwise.

Under conditions prevailing in Scotland and the north of England the usual amounts of seed sown are as follow:

| | | | |
|---|---|---|---|
| Swedes, | 4½ lb. for early sowing to | 3 lb. for late sowing. |
| Yellows, | 4 ,, ,, ,, | 3 ,, ,, |
| Whites, | 3 ,, ,, ,, | 2½ ,, ,, |

In the remainder of England smaller quantities are required, roughly ½ lb. per acre less. Undue sparing of seed is not a profitable practice, in spite of the fact that the majority of the plants will be rejected later. A fairly thick braird provides protection to the delicate seedlings from effects of weather, and they suffer less severely from the Turnip Fly. Too thick seeding should be avoided, however, as the plants become spindly and are more difficult to single.

It sometimes happens that there is just sufficient moisture in the soil to germinate the seed without supplying the young plants with enough to continue their growth, and they consequently die off. This most frequently happens when care has not been taken to prevent the land from drying out during cultivation. Or the seedlings may be killed off by an attack of the Turnip Fly, which is particularly destructive just after the cotyledons appear above the ground. In both of these circumstances the drills should be harrowed down, set up anew, rolled, and seed sown again. If the season be then too far advanced for sowing swedes, as is often the case, Yellow or White Turnips, as the case may be, should take their place.

Under normal conditions the pair of small smooth notched cotyledons appear above the ground in from a week to a fortnight (three or four days in very favourable circumstances), at which stage turnip seedlings cannot be distinguished from those of runch and charlock. Soon afterwards the first foliage leaf appears, when the plants approach the singling stage. This implies the spacing of individual robust plants at a desired distance apart and the rejection of surplus ones.

## Operations after Sowing the Seed.

Nothing, as a rule, requires to be done till the young plants are ready for singling. Some weed seedlings certainly make their appearance along with the turnips, but not in such profusion as to smother them. However,

when the land is very foul, and especially if the cleaning operations have been negligently carried out, weeds sometimes come up so abundantly as to hinder growth seriously. In such circumstances the drill harrow, or if the land be ridged the modern scuffler, should be run along the drills to kill the weeds, but care should be taken not to set these implements so wide as to injure the seedling turnips.

**Singling.**—The young turnips are ready for singling when the first foliage leaf has been fully formed. They are then said to be in the " rough leaf ". This stage is attained in from three weeks to a month after sowing, though it may occasionally be delayed to six weeks. Swedes are slower in coming to the singling stage than Yellow and White Turnips. Delay in singling greatly retards the later growth.

Immediately prior to singling, the drill scarifier or scuffler is passed along the raised ridges. This pares weeds off the ridges, reduces the size of the drills, and kills weeds between them. In the absence of this particular implement, and in the case of roots sown on the flat, its place is taken by the drill grubber. This preliminary work is followed occasionally, but by no means regularly, where turnips are sown on the flat, by harrowing across the rows (at right angles to the direction of sowing) with the object of pulling out some of the plants and so reducing the amount of singling, but this is a practice which can only be followed when the braird has been very regular and the land light.

When there is a fairly big acreage to single with a limited supply of labour, it is always advisable to start operations before the whole of the area is quite ready, as delay in completing the work greatly reduces the final yield, so quickly do the young plants grow under moist warm conditions at this time. It should be the aim of the grower to have the job completed in ten days. On the other hand, singling too early is to be as strongly deprecated, for the want of protection from the other plants and the paring away of the high ridge of soil seriously impede growth, on account of exposure to cold and drought.

There are several methods of singling practised throughout Britain. No matter which one be adopted, the work must be carefully carried out. Care should be taken to leave only the most robust plants at a uniform distance apart, and to avoid drawing much soil into the space between the drills with the discarded plants, as this both undesirably favours their growth there and interferes with inter-drill cleaning operations. The ridges are reduced almost to the soil level and the singled plants lean over, but they soon straighten up again. Carefully conducted experiments prove that the yield can be increased to the extent of fully 2 tons per acre by methodical singling. The most desirable distance between individual plants in the drill varies with soil and variety from 8 to 12 in. With the majority of Yellow Turnips, Purple, and Bronze Topped Swedes on loamy soils the best distance is

10 in., as is shown in the following experiment carried out by the West of Scotland Agricultural College.

TURNIP THINNING EXPERIMENT

| Variety. | Width of Drill. | Distance between Plants. | Yield per Acre. | |
|---|---|---|---|---|
| | Inches. | Inches. | Tons. | Cwt. |
| Swedes .. .. | 27 | 12 | 25 | 8 |
| | | 10 | 29 | 4 |
| | | 8 | 28 | 9 |
| Common Turnips | 27 | 12 | 29 | 0 |
| | | 10 | 33 | 15 |
| | | 8 | 29 | 6 |

On less suitable soils, in the case of turnips and Green Top Swedes, both of which produce smaller sized roots, the distance should be reduced to 8 in. The same applies to late sown turnips intended for sheep folding in spring, when abundant leaf surface is as much desired as root.

Turnips sown broadcast as a catch crop are not singled. They are often thinned out roughly by harrows to give more leaf surface.

The methods of singling are: (*a*) by hoe, (*b*) by hoe and hand, (*c*) by hand, and (*d*) by thinning machine and hoe.

Singling by hoe is by far the most common. In this case the operator draws the surplus plants with as little earth adhering as possible into the space intervening between the drills, taking care to leave single robust plants. In using the hoe there is a tendency on the part of many operators to dig the plants out instead of drawing or pushing them, thereby leaving the rows of turnips below the level of the adjoining soil. This allows the rejected plants to grow readily, interferes with inter-drill cultivation, and thereby reduces the yield. Such a practice must be carefully guarded against. An experienced worker will hoe on an average $\frac{1}{4}$ to $\frac{1}{3}$ ac. roots per day under favourable conditions.

Sometimes the singling is carried out in two operations. The surplus plants are drawn out by hoe, leaving clumps behind at intervals. Workers following those hoeing then single out the most robust plant in each bunch.

At other times, especially on the heavier types of soil, such as exist in Ayrshire, the entire operation is carried out by hand. The operator moves along the drill on his knees, draws out the plants to be rejected, shakes the soil from them, casts them into the drill, and leaves only the best plants. By this method the work is usually very carefully done and

the rejected plants die quickly. Hand singling suits this class of soil very well, but it is a slower process. A worker can do from $\frac{1}{8}$ to $\frac{1}{4}$ ac. on an average per day.

Machines are occasionally used. They are of recent introduction, and have not been extensively employed so far on account of their only being able to thin out the plants without singling them. They have the further disadvantage that they cannot make allowance for places where gaps occur, due to faulty brairding, and may draw out clumps of plants which, growing alone, should be retained for singling. Where the machine is used, workers follow along the drills and perform the singling operation either by hand or hoe. Machines can be profitably employed when the crop is intended for folding with sheep, in which case careful singling is less important.

When blank spaces exist as the result of uneven brairding, swedes may be transplanted with success if care be taken to select strong plants and remove them without injuring the roots. Transplanting is much less successful with Yellows and Whites, both of which are more delicate than swedes at this stage.

**Inter-drill Cultivation and Weeding.**—Immediately after singling, the drill grubber is passed along the drills, doing one drill at a time to bring any of the rejected plants which may have taken root again to the surface. The action of heat and wind soon kills these; this is greatly facilitated if the grubber be succeeded by the drill harrow. As far as possible a grubber and harrow should immediately follow those singling, as half a day's exposure will kill the cast plants at this stage.

If it is desired to top dress the crop with nitrate of soda this is best done now. In a few days after singling, especially if the top dressing be followed by a few showers, the young plants begin to stand up in the rows and rapidly produce more foliage leaves.

The crop should then be hoed with hand hoes to kill any weeds which may be present in the rows of turnips. This practice in addition to killing weeds produces a fine mulch between the plants and greatly increases their vigour, especially in a dry season. After this operation the drill harrow should be employed repeatedly, so long as the leaves admit of it, to stir up the soil and keep down weeds between the rows. This harrowing maintains a mulch which, in addition to restraining the growth of weeds, keeps down undue evaporation of water and allows the nitrifying processes to be carried on under the most favourable conditions. Care should be taken in carrying out this work not to set the drill harrow too widely as many roots would thereby be injured, leaving cuts favourable for the entrance of fungi and bacteria, a common cause of disease later in the season. In the drier parts of the south of England particularly, constant drill harrowing goes a long way towards reducing the destructive effects of mildew. This disease is most destructive after periods of long

drought when the growth of the plant is restrained, but the continuous supply of moisture afforded by the presence of a mulch maintains a fairly constant water supply and hence steady growth.

Inter-drill cultivations should be continued until injury would be done to the leaves by the horses and implements travelling along the drills. This does not usually take place until the leaves have almost met in the drills. In the lighter classes of soil no further tillage operations are carried out till the roots are ready for lifting, but on the heavier soils it is common to earth up the roots very lightly, to provide a shallow watercourse. Heavy earthing up favours the production of fanged roots.

Bulbing of the roots does not usually commence till the leaves have almost met in the drills, but thereafter rapid swelling takes place till the roots are ready for lifting. Growth is particularly active in warm moist autumn months.

## Harvesting of the Crop.

The indication of both turnips and swedes having reached maturity is that the leaves begin to wilt and, in the case of common turnips, acquire a yellowish brown tint. The leaves of swedes become very much contracted and curl along their edges. The order of harvesting the varieties is in the order of the rate of their maturing, White Turnips being harvested first and Green Topped Swedes last.

White Turnips are usually ready for folding or lifting by the end of September, and unless raised when they come to maturity decay sets in. In addition they are very susceptible to the effects of frost. They are usually either lifted with the leaves adhering and carted for feeding to stock, or sheep are folded on them. As in all cases where folding is practised, it is advisable to allot the field in portions to the sheep by the use of movable hurdles; wastage of roots by soiling is thereby greatly reduced. All the White Turnips are usually consumed by the middle of November, after which the pale yellow-fleshed types of Yellow Turnips are used. These are usually pulled for direct consumption, but Fosterton Hybrid may be successfully stored for at least a short period. After all these softer types have been disposed of, yellow varieties come into use. Frequently only these and swedes are grown; they may be then used from the beginning of November, in which case they are pulled and fed to stock with the leaves adhering, so long as the leaves are green, or they are folded with sheep. As soon as hard frost sets in, however, those remaining should be topped, tailed, and stored.

Swedes are the last to be lifted and the last to be consumed. Late varieties of swedes increase in weight well into February unless a prolonged period of frost and snow sets in. The earlier types, however, e.g. Best of All, make little progress after Christmas. Swedes can be used for direct consumption from the field, or they may be stored for later use.

On account of the custom of growing Yellow or soft varieties for early use they are nearly always retained for late winter or early spring, and, in the majority of cases, have to be stored to prevent their destruction by frost and game, and to ensure that the land may not be poached by carting off the crop during the winter months. Where no hard winter frosts are experienced, such as in the immediate proximity of the sea (e.g. the coast of Kintyre and Ayrshire), and on soils with a dry bottom throughout the winter (e.g. parts of Aberdeenshire), swedes may be left growing all winter; they are merely topped and tailed and carted to stock as required. Care must then be taken that the land is not poached during wet weather.

**Topping and Tailing.**—Prior to storing or carting from the field, swedes, and usually Yellows, are topped and tailed. This process is sometimes referred to as shawing. It is not the custom to do this with White or early used Yellow Turnips because the leaves possess a considerable amount of feeding value if consumed before decay has set in.

Topping and tailing implies the cutting off of the leaves and the lower part of the tap-root and small rootlets. Great care should be taken not to cut the root, as this sets up "bleeding", thereby entailing considerable loss of nutritive materials and the laying open of the delicate storage tissue to attacks of fungi and bacteria. Swedes should be cut at the base of the neck and Yellows at the base of the crown. The work is usually carried out by hand, using a strong knife about 9 in. long. An experienced worker can do about $\frac{1}{4}$ ac. per day. In working over a field, the roots from four adjoining drills are thrown into one row for convenience in lifting later by cart.

Topping and tailing machines have been recently introduced and have realized a moderate degree of success. While they carry out the operation more speedily, they are less efficient than hand workers.

Some growers prefer to cart swede shaws and even the wilted shaws of Yellow Turnips to their steadings for the feeding of dairy cows. Though these leaves possess a certain amount of feeding value, the practice cannot be looked upon with favour; they are a common cause of strongly tainted milk, and set up scouring very readily. Besides, leaving them on the land provides the soil with a store of organic matter which reacts very beneficially on the succeeding crop, especially on light soils and those to which dung has not been applied as one of the forms of manure. The leaves should be spread over the land evenly before next ploughing it, otherwise the rows where they have been left will be clearly seen in the succeeding cereal crop.

After topping and tailing, the roots are left in the rows for a few days to allow of their being stored in a dry condition.

**Methods of Storing.**—There are several methods of storing, each used in accordance with the circumstances under which it is desired to

make use of the crop. No matter which one be adopted, it is always advisable to ensure that the turnips are dry and free of frost when stored. If topped and tailed and later stored during frosty weather, they rot very readily during the storage period.

The common methods are as follow:

1. The roots, after topping and tailing, are put into small heaps of three to four loads. This is frequently done when it is desired to feed them to sheep. The heaps may be either conical or pyramidal in shape. They should, if possible, be uniformly distributed throughout the field, so that it may be folded in sections with the aid of hurdles, and allow of the whole area being uniformly trampled by the sheep. The heaps are covered over with straw, and a layer of from 4 to 6 in. of earth is placed over the thatch as a protection from frost.

2. Heaps of from sixteen to twenty loads are made on the driest portions of the field. They are usually put up in the form of squares from 3 to 4 ft. deep, and are thatched all over with straw, the sides alone being covered with earth as in (1) above. Roots stored in this way are also used for sheep feeding.

3. When roots are intended for feeding to cattle they are usually carted to the steading, where they are either stored in a shed or court kept for the purpose, or put into large heaps of from one hundred to one hundred and fifty loads at some spot convenient to the byres or feeding courts. In this case there is no need for thatch. Some waste straw or hay is simply thrown over them to protect the outer roots from frost.

4. The turnips are often ploughed in where the soil is open and not liable to lie in a wet condition during winter. This operation is carried out by first opening a deep furrow with the swing plough, pulling the roots of the two adjacent drills, and placing them in the newly opened furrow with their roots downwards and their leaves projecting upwards. They are then covered in on the return journey of the plough and remain in the field till required in the spring, when they are ploughed out, topped and tailed, and carted to the steading. The adoption of this system often produces a considerable increase in weight, but it can only be carried out on soils which will not be poached by trampling during the winter months.

5. Methods 1 or 2 and 3 are often adopted on the same farm where both cattle and sheep are kept. The combination of 3 and 4 calls for special attention. Several rows are alternately stored at the steading and ploughed in, so that the field eventually appears to be divided into bands. The roots which are ploughed in are later turned out for sheep to gnaw.

### Yield per Acre.

The yield per acre is a very variable feature, as has already been pointed out in discussing soil, climate, manurial treatment, and cultivation. It

even differs from year to year on the same soil as the result of variations in weather. Under ordinary circumstances, however, in Scotland and the north of England a properly treated crop of Yellow Turnips and soft turnips should yield 24 tons, whilst a crop of at least 22 tons of swedes should be obtained. In the midlands and south of England yields are smaller; they usually average about 16 tons, but they are often much less than this, and seldom exceed 20 tons.

Much larger yields than those mentioned are very often grown. In many cases, particularly in the east and north-east of Scotland, they exceed 30 tons, and when grown for purposes of competition occasionally approximate to 50 tons per acre.

The following table shows the yield per acre of turnips and swedes as returned by the Ministry of Agriculture and Fisheries for the years 1918–21. These figures are considerably less than those stated above, but it is to be remembered that the yields suggested are those which would be expected from crops grown on suitable soils and given good treatment.

YIELD IN TONS PER ACRE OF TURNIPS AND SWEDES

| Year. | England. | Wales. | Scotland. | Ireland. |
|---|---|---|---|---|
| 1918 | 13·1 | 15·0 | 13·9 | 18·0 |
| 1919 | 11·3 | 13·1 | 16·8 | 16·4 |
| 1920 | 14·5 | 12·8 | 18·1 | 14·9 |
| 1921 | 7·1 | 12·6 | 17·4 | 14·6 |

## Insect Pests.

The turnip crop is susceptible to the attacks of many insect pests. These are divided into two main groups, viz. (*a*) those attacking the foliage, and (*b*) those attacking the root.

(*a*) The foliage pests can be subdivided, according to the nature of their attack, into insects which (1) feed on the cotyledons, (2) feed on the rough leaves, (3) burrow up the leaf stalks.

(1) The only offender here is the Turnip Fly (*Phyllotreta nemorum*), which in its adult condition is particularly destructive of the very young plants, and probably the most pestilent insect which the turnip crop encounter from year to year.

(2) Those affecting the rough leaves include both larvæ and adults of the Turnip Fly (*Phyllotreta nemorum*), caterpillars of the Diamond-back Moth (*Plutella maculipennis*), adults of the Turnip Sawfly (*Athalia spinarum*), and all stages of the Plant Lice (*Aphides*),

(3) An insect of the genus *Phytomza* has made its presence most disagreeably observed during recent years by burrowing up the leaf stalks.

(*b*) The root pests can be subdivided into two sections according as they cause swellings or not.

(1) The Turnip and Cabbage Gall Weevil (*Ceuthorynchus sulcicollis*) is the insect responsible for the swellings in which the larval stage may be often found *in situ* both when the plants have just acquired their leaves and when full grown in early winter. These swellings are often mistaken for the excrescence of finger-and-toe disease.

(2) Insects affecting the roots without causing swellings mainly include wireworms (larvæ of *Agriotes lineatus*, *A. obscurus*, and *A. sputator*) and surface caterpillars (larvæ of *Agrotis segetum*, *A. exclamationis* and *A. pronuba*).

Details of these insects, appearance of the plants when affected, and methods of controlling them are given in the article on Insect Enemies of Root and Potato Crops, p. 272.

It should be noted that insect pests not only do damage by reducing the assimilating tissue and feeding on the stored material, but they also make openings which are favourable for the entrance of destructive moulds and bacteria.

**Fungoid Pests.**

Fungoid pests attack both foliage and roots. Those affecting the foliage are mostly of two forms of mildew—*Peronospora parasitica* and *Oidium Balsamii*, a type of Erysiphe. Both of these attack the crop to the greatest extent during a long period of drought following one of very active growth. They are responsible for great damage, especially in the south of England.

The most widespread root trouble, finger-and-toe, is caused by the slime fungus *Plasmodiophora brassicæ.* It abounds throughout the whole country and causes immense losses annually, especially on soils deficient in lime. Forms of dry and wet rot are also attributable to various types of fungi, a notable one amongst these being of the genus *Phoma*, which causes cracking of the roots. In many cases rot is a secondary effect of damage done during cultivation, when various forms of bacteria and fungi enter the roots through the abrasions and commence their destructive work.

Certain bacteria are responsible for disease of roots. These gain admittance through the air pores of the leaves, and work their way through the tissues of the plant (see Diseases of Root and Potato Crops, p. 225).

## Cost of Production.

See COST OF PRODUCTION OF POTATOES, TURNIPS, ETC., p. 212.

In many cases the cost of production of the turnip crop exceeds the value of the produce, assuming the price per ton of the turnips to be market value less cost of marketing. This loss is often more apparent than real for two main reasons. Firstly, whilst the whole cost of the cleaning operations and application of dung to the crop may be charged against the crop, the benefits of these are also of great advantage to the other crops in the rotation. Indeed, they form essential parts of the cultivation of these crops, taking the rotation as a whole. Secondly, the actual feeding value of the roots may greatly exceed the assumed market value. In the absence of other forms of green material they form an almost absolute necessity for the maximum production of milk or meat in the winter months. Without some form of green foods—and of these the turnip is one of the most convenient—the most economical use of concentrated feeding stuffs cannot be attained.

There is naturally, however, an economic balance, and in very dry districts or on very heavy lands, the small crops and large working expenses may not make the utilization of the crop at all remunerative. Under such circumstances the place of turnips can be taken by soiling crops and silage. These can be depended on to give more economic returns. Yet, where fairly good crops can be grown, it is unlikely that the turnip will be displaced by silage for winter use, for not only does the crop by itself leave a fair return, but the partial fallowing of the land periodically also makes possible its recuperation from lack of efficient aeration.

## Utilization of the Crop.

A small part of the annual yield is devoted to human consumption as a vegetable. Growers adjoining industrial centres derive quite a considerable revenue from the sale of the roots, but the price realized does not merit transport over long distances, as in the case of potatoes.

Practically the whole of the crop is consumed by stock, principally represented by cattle and sheep. To a very much less extent turnips and swedes are fed to pigs and horses. For cattle of all ages indoors they promote good appetites and healthy condition.

Fattening bullocks may receive up to 1 cwt. per day; the most economical returns, however, are got from feeding about 80 lb. in conjunction with suitably balanced rations of concentrated feeding stuffs. Dairy cows may be given up to 70 lb. per day, but better flavoured milk and produce are obtained by feeding a maximum of 56 lb. in conjunction with suitable concentrates. Large amounts of turnips taint both milk and produce. To prevent this, even when fed in moderation, they should be fed *after* milking. Turnips are also excellent food for young stock, when fed along

with concentrates. Two-year-old dairy heifers may receive 35 lb. per head per day, and yearlings should be fed from 16 to 20 lb. Winter calves benefit from receiving from 6 to 8 lb. per head per day, cut into fingers. There is no need for cutting turnips and swedes for mature dairy cows or fattening stock, nor is it necessary to cook them; but it is better to cut them into slices for young stock which have not yet got all their permanent teeth, and for cows with defective teeth.

Turnip and swede tops are often fed to dairy cows. The practice cannot, however, be recommended, for reasons already indicated. When they must be fed on account of deficiency in quantity to cover the winter's need of turnips, they should be given in moderate amounts, not exceeding 35 lb. per day.

Turnips provide a favourite food for sheep. In late autumn, fattening hoggs, and ewes to be flushed preparatory to mating, may be turned on to growing crops of White and Yellow Turnips with advantage. They then use both the leaves and roots. It is advisable to allot the crop in portions by introducing the use of movable hurdles.

During winter it is better to feed both Yellow Turnips and swedes, which have been previously stored in the field in small heaps (see "Storing", p. 113), in the cut state. Fattening hoggs should receive about 16–20 lb. per head per day along with $\frac{3}{4}$ to 1 lb. concentrates and $\frac{1}{4}$ lb. hay. Ewes in lamb should not get more than 8 lb. per head. Feeding of large quantities gives rise to large "soft" lambs. After lambing, however, they may be fed 16 to 20 lb. per head per day with success. An average crop of 24 tons swedes is usually sufficient to feed off about 30 hoggs over a fattening period of 16 weeks.

In some cases sheep are simply turned on to eat the swedes as they grow, but this practice is less economical than that indicated. On the down lands of Wiltshire late sown turnips are consumed as they grow in the early part of the following year, when their foliage materially adds to the nourishment obtained from the small roots.

Turnips and swedes are fed to pigs when no other green feeding is available. They should be fed in small quantities, and it is unnecessary to cut them. One or two swedes are very useful for feeding to horses with the evening feed, but the allowance should never exceed 8 lb. per day.

In feeding value the following are approximate equivalents: 20 cwt. swedes, 25 cwt. Yellow Turnips, 30 cwt. White Turnips.

# COMPOSITION AND NUTRITIVE VALUE OF SWEDES AND TURNIPS

By PROFESSOR R. A. BERRY, Ph.D., F.I.C.

The turnip plant is a biennial, and the first year's growth produces a fleshy root or bulb surmounted by a tuft or rosette of leaves. In the bulb is stored the material necessary for the formation of seed in the second year. The stored material consists of compounds elaborated in the leaf and of mineral salts absorbed from the soil. Together they form the nutritive substances of the root so valuable for the feeding of stock. This nutritive material consists largely of sugars, a small proportion of albuminoid (protein) and of non-albuminoid nitrogen, a little fat, some mineral salts, a small amount of fibre, and traces of other compounds. The sugars and a considerable part of the other substances, with the exception of the fibre, are in solution in the sap and are digestible. Together they form the dry matter which amounts to about 10 per cent of the weight of the root, the remaining 90 per cent being water. Surrounding the root is a skin of lignified tissue forming a protective layer which varies in thickness in different varieties and under different conditions of growth. The skin contributes largely to the fibrous content of the root.

The leaves or tops, which are not as a rule employed for feeding purposes, are cut off and returned to the soil at the time the crop is lifted, the topped roots being stored until required for use. Instead of lifting the roots the crop (leaves and root) is often fed off on the ground with sheep, and the manurial constituents of the crop contained in the excreta returned direct to the soil. The tops form about 15 per cent of the weight of the crop, but the proportion is subject to variation according to the influence of variety, season, and soil.

The turnip crop is cultivated for the purpose of providing a succulent food for the winter feeding of stock. The present acreage and yields are shown in the following figures taken from the agricultural returns for 1922.

| | Total Arable Land. | Under Turnips. | Percentage under Turnips. |
|---|---|---|---|
| | Acres. | Acres. | |
| England .. | 10,583,258 | 775,212 | 7·3 |
| Scotland .. | 3,338,068 | 404,112 | 12·1 |
| Wales .. | 727,257 | 45,916 | 6·3 |

Although the percentage of arable land under turnips is relatively small, yet the total yield of roots amounts to a considerable figure as shown below.

| | Average Yield per Acre, 1909–18. | Total. |
|---|---|---|
| | Tons. | Tons. |
| England .. .. | 12·9 | 10,000,000 |
| Scotland .. .. | 16·4 | 6,627,000 |
| Wales .. .. | 15·3 | 702,500 |

The value of the crop at 15*s*. per ton amounts to £7,500,000 for England, £4,975,000 for Scotland, and £527,000 for Wales.

A comparison of the analysis of turnips with that of sugar beet made during the past fifty or sixty years shows that the composition of the turnip has not altered very much whilst that of the sugar beet has been greatly improved. This result is due to a difference in the methods adopted in the selection of the roots for seed production. In the case of sugar beet it was found that when size and shape of the root were taken as the basis for selection no marked improvement in the composition of the crop was made. Selection according to the specific gravity of the root and afterwards that of the juice was tried with some success. But the method which accounts for the great improvement in the composition of the crop, and the one which has been followed for the past thirty or forty years, is based upon the sugar content. A core is taken from each root which is numbered, the percentage of sugar determined in it, and the roots found to be the richest in sugar are stored and grown for seed production in the following year. Coring does not seriously damage the root. The figures given below show the effect of this method of selection upon the composition of the crop.[1]

| Year. | Sugar. | Purity of Sugar. |
|---|---|---|
| | Percentage. | Percentage. |
| 1892–93 | 11·88 | 84·6 |
| 1893–94 | 12·68 | 85·3 |
| 1894–95 | 12·12 | 85·0 |
| 1895–96 | 13·79 | 87·0 |
| 1896–97 | 13·24 | 87·4 |
| 1897–98 | 14·33 | 87·9 |
| 1898–99 | 15·13 | 87·8 |
| 1899–1900 | 14·6 | 87·3 |

In the case of turnips the method of selection has been based mostly upon botanical features of the root, such as size, shape, colour of skin and flesh, keeping qualities, &c., and as already remarked no great improvement in the composition and feeding value of the crop has resulted.

[1] See The Sugar Beet Crop, p. 147.

However, during the past two decades a considerable amount of investigation into the composition of turnips and the extent to which the crop is subject to variation has been made in this country. The object in view is to determine the identity of the constituents which give to the turnip crop its feeding properties. Ultimately it is hoped to bring about improvements in the nutritive value of the crop by breeding on the lines indicated as a result of these investigations.

The swede and the common or Yellow Turnip and the White Fleshed Turnip are the varieties of turnips in cultivation.

## Swede Turnip.

The average composition of this crop is as follows:

| | Root. | Tops. |
|---|---|---|
| Water .. .. .. | 88·5 | 88·4 |
| Crude protein .. .. | 1·3 | 2·2 |
| Soluble carbohydrates .. | 8·1 | 5·3 |
| Fibre .. .. .. | 1·2 | 1·5 |
| Oil .. .. .. .. | 0·2 | 0·5 |
| Ash .. .. .. .. | 0·7 | 2·1 |
| Dry matter .. .. .. | 11·5 | 11·6 |

Soluble carbohydrates form the largest constituent of the dry matter. They consist mostly of sugars and pectocelluloses. The principal sugar is grape sugar, and there is also present a small percentage of cane sugar. The crude protein includes pure protein, which amounts to more than one-half of the nitrogen compounds, and the remainder is non-protein nitrogen (amides). The fat present is so small in amount as to be almost negligible. But the ether extract in addition to the fat contains colouring bodies and traces of other substances. The flavour of turnips and other cruciferous plants is due to the presence in small amounts of oil of garlic (allyl sulphide), $(C_3H_5)_2S$, and of mustard oil (allyl isothiocyanate), $C_3H_5CNS$. Of the mineral or ash constituents present phosphoric acid ($P_2O_5$) forms 0·1 per cent, potash ($K_2O$), 0·3 per cent, and lime ($CaO$), 0·1 per cent of the weight of the root. Wilson states the composition of the ash of the root and tops of swedes to be as follows:

| | Bulb. Percentage. | Tops. Percentage. |
|---|---|---|
| Potash, $K_2O$ .. .. .. | 34·1 | 15·21 |
| Soda, $Na_2O$ .. .. .. | 7·96 | 2·84 |
| Lime, $CaO$ .. .. .. | 9·93 | 28·49 |
| Magnesia, $MgO$ .. .. | 2·61 | 2·81 |
| Oxide of iron .. .. | 0·46 | 1·68 |
| Phosphoric acid, $P_2O_5$ .. | 9·88 | 6·17 |
| Sulphuric acid, $SO_3$ .. | 1·81 | 3·99 |
| Chloride of sodium .. | 8·13 | 15·30 |

Vitamins, namely fat soluble A, water soluble B, and vitamin C, are also contained in the root. The dry matter therefore consists of the substances enumerated above. It is determined by drying the fresh sample until practically no further loss in weight occurs, the loss being water. Of the constituents of the dry matter sugars form about 70 per cent and the nitrogen compounds about 10 per cent. Between 70 and 80 per cent of the constituents of the root are contained in the sap, and they form the water-soluble part of the dry matter.

The specific gravity of a sound turnip root is round about 0·9 to 0·95, but for obvious reasons it will vary according to the chemical content of the root. Owing to air spaces contained in many roots, usually at the base of the neck, the specific gravity is not always a guide to the richness of the root in nutritive substances.

### Variation in Composition.

Individual roots are not of the same composition throughout. This was found by Wood and Berry to be the case with mangolds, and Hendrick showed that swedes varied in a similar way. Generally the percentage of dry matter is least in the middle of the root, increasing towards the outer region, and it is greatest at the apex. It will be seen, therefore, that the composition of a vertical sector or of a core taken in a horizontal direction, that is at right angles to the axis of the root, should represent approximately the composition of the whole root.

Again, there is a great difference in the percentage of dry matter between individual roots of the same variety. Out of one hundred roots taken promiscuously from a heap, but avoiding the very small ones, Wood and Berry found the lowest percentage of dry matter in any single root to be 7·8 per cent and the highest to be 15·6 per cent, the average being 11·8 per cent. As a rule the larger roots of the same crop contain the lower and the smaller roots the higher percentages of dry matter. Although some individual large roots are just as rich in dry matter as the average small root. Roots containing soft corky tissue (foggy roots) are of inferior feeding value. The existence of such marked differences in composition between individual turnips makes it possible to devise methods of improvement based upon the chemical content of the root as in the case of sugar beet.

The variety, season, soil, stage of ripeness, &c., exercise an influence upon the composition of turnips. Of these factors the effect of variety is perhaps the greatest. Mangolds can be grouped into five distinct types with marked botanical and chemical features. No such well defined differences are found in the varieties of swedes. The following is a general grouping of the swedes in cultivation, together with the average composition of each group. The figures are taken from the results of an experiment carried out at St. Andrews.

| | Dry Matter. Percentage. | Sugar. Percentage. | Sugar per Acre. Tons. |
|---|---|---|---|
| Purple Top .. | 10·48 | 6·85 | 1·666 |
| Bronze Top .. | 10·78 | 6·69 | 1·763 |
| Green Top .. | 10·98 | 6·84 | 1·740 |

Each type is subdivided into strains according to certain botanical features, such as the shape of the root, whether round, tankard, or oval shape, early or late ripening, &c.

As regards the effect of season, soil, and manuring on the composition of turnips, the data available are not sufficiently definite to enable figures to be quoted with certainty, but there is evidence accumulating to show that the proportion of protein to non-protein nitrogen is higher in roots grown in a locality with a light rainfall, compared to a locality with a heavy rainfall. Undoubtedly each of the above-mentioned factors affects the growth and composition of the crop. The manufacture and storage of sugar in the root takes place largely in the months of September and October, so that the weather conditions in that period are an important factor. A good supply of moisture and a moderate temperature appear to be the best conditions for the successful cultivation of this crop. To emphasize the effect of the length of the growing period upon the composition of root crops, the writer found in the case of sugar beet that the crop lifted early in the month of December contained 15·7 per cent of sugar and 22·8 per cent of dry matter, but when allowed to grow on under suitable climatic conditions until the end of February before lifting, the percentage of sugar amounted to 19·0 per cent and the dry matter to 25·1 per cent. It does not follow, however, that this result would apply to other root crops.

Manures, especially phosphatic and potassic, not only affect the yield, but also the composition of the crop. More data on these points are, however, required before figures can be given. At the same time it is a well-established fact that a deficiency of potash in the soil depresses the sugar content and lowers the feeding value of root crops.

## Nutritive Value.

The percentage of dry matter is taken as a good index to the feeding value of a root crop. That being so it follows that the variety of swedes to cultivate is the one which yields the largest return in dry matter per acre. Knowing the yield per acre and the percentage of dry matter in the crop, this figure is easily calculated. Some varieties may be large yielders with a lower content of dry matter and others moderate yielders with a higher content of dry matter. Although carbohydrates form the bulk of the dry matter and account for its principal nutritive properties,

the nitrogen and mineral constituents also contribute. But before it is possible to apportion the relative importance of the separate constituents of roots, further feeding experiments with this object in view are required. In connection with this point the nature of the other foods given along with the turnips, also whether for fattening or milk production, are factors which would require to be considered. The following figures show the total and the digestible constituents in a crop of swedes.

| | Total. Percentage. | Digestible. Percentage. |
|---|---|---|
| Protein, crude .. .. | 1·3 | 1·1 |
| Protein, pure .. .. | 0·8 | 0·3 |
| Soluble carbohydrates .. | 8·1 | 7·5 |
| Crude fibre .. .. .. | 1·2 | 0·8 |
| Oil .. .. .. .. | 0·2 | — |

Calculated from the above figures, the albuminoid ratio works out at 1 : 7. Starch equivalent, gross, 9·2; net, 7·3 per 100 lb.

Faber found in experiments on milk production that 36 lb. of mangels had a greater effect on the milk yield than 36 lb. of turnips. The analysis of the former showed a dry matter content of 12·96 per cent and of sugar 7·54 per cent, and for the latter of 8·88 per cent and 3·37 per cent respectively, thus connecting the dry matter and the composition of roots with their value for milk production. Further experiments showed that 20 lb. mangels or 24 lb. turnips had the same feeding value as 2 lb. meal. The albuminoid content and the starch equivalent is the best basis to take for the purpose of comparing the relative nutritive value of swedes with that of other crops. For tables showing the composition, the starch equivalent and other food values for crops, the reader is referred to books on agricultural chemistry.

Succulent foods such as root crops, when fed in large quantities to cows, are generally supposed to stimulate milk secretion and to yield a more watery milk. The results of careful feeding experiments, however, have disproved this assumption. It was found that cows receiving an allowance of turnips amounting to 112 lb. per day produced a smaller yield of milk but richer in fat than cows receiving one-half the root allowance. Excessive feeding of turnips or swedes is also supposed to give a milk with a turnipy flavour. This flavour, however, is more often due to the action of certain bacteria on the milk. The writer found that Ayrshire cows receiving a daily allowance of 1 cwt. of roots scoured rather badly and lost in condition. But fed in moderate quantities swedes are an excellent food for cows. Store cattle are often fed on straw and roots only and are kept in excellent health.

An average crop of swedes removes the following amounts of nitrogen, phosphoric acid, and potash in pounds per acre:

| | Bulbs. | Tops. | Total. |
|---|---|---|---|
| Nitrogen .. .. .. | 70 | 28 | 98 |
| Phosphoric acid, $P_2O_5$ .. | 16·9 | 4·8 | 21·7 |
| Potash, $K_2O$ .. .. | 63·3 | 16·4 | 79·7 |

The manurial constituents per ton of swedes are:

| | Pounds per Ton. | Percentage. |
|---|---|---|
| Nitrogen .. .. .. | 4 | 0·2 |
| Phosphoric acid .. .. | 2 | 0·1 |
| Potash .. .. .. | 7 | 0·3 |

## Common or Yellow Turnip.

Average composition of this crop is as follows:

| | Total. Percentage. | Digestible. Percentage. |
|---|---|---|
| Protein, crude .. .. | 1·0 | 0·6 |
| Protein, pure .. .. | 0·6 | 0·2 |
| Soluble carbohydrates .. | 5·7 | 5·2 |
| Fibre .. .. .. | 0·9 | 0·3 |
| Ash .. .. .. | 0·7 | — |
| Dry matter .. .. | 8·5 | — |

It will be seen from the above analysis that the common turnip is of lower feeding value than the swede. The causes which produce variation and the extent of these in this crop are similar to those which produce variation in swedes.

The two principal varieties are the yellow- and white-fleshed types, an average analysis of which is given below.

| | Dry Matter. Percentage. | Sugar. Percentage. | Sugar per Acre. Tons. |
|---|---|---|---|
| Yellow-fleshed turnip .. | 8·29 | 4·7 | 1·537 |
| White-fleshed turnip .. | 7·82 | 4·03 | 1·49 |

# THE MANGOLD CROP

By WILLIAM STRANG, B.Sc., N.D.A.

Mangolds, now commonly called mangels, were first grown in England about 120 years ago, and since then the area devoted to this crop has gradually increased. In the year 1922 in England and Wales 422,000 ac. were grown, and in Scotland 2008 ac. Where a large head of live stock is kept, it is one of the best crops for providing a large weight of succulent and nutritive material for winter feeding. In districts where the production of silage has been developed there is a tendency for that partly to replace mangels; but whether in the future the area devoted to mangels will be much reduced on this account will depend on which of the two foods can be produced the more economically.

## Botanical Description.

The mangel, which belongs to the natural order *Chenopodiaceæ*, is a variety of the Common Beet (*Beta vulgaris*). It is also known as Field Beet and Mangel Wurzel. To the same order belong such common weeds as Goosefoot (*Chenopodium album*) and Orache (*Atriplex hastata*).

The mangel is a biennial plant which, in the first season, stores food material in a swollen part of the plant, erroneously termed the " root "; in the following season flowers and fruits are produced.

**Seed and Seedling.**—That which is popularly known as mangel seed really represents a mass of two or three fruits, each containing a true seed, which is of the endospermic type. In size the true seed resembles that of a turnip, but differs from it in the possession of a kidney shape and dark smooth skin.

Germination takes place under suitable moisture, heat, and air conditions, and the radicle (seed root) penetrates the soil where it forms a primary tap-root. Meantime that portion between the cotyledons and the radicle extends into a definite region, called the hypocotyl. Growth of the hypocotyl raises the cotyledons above the ground where they function as the first green leaves, which are long and narrow. Shortly afterwards the plumule bud gives rise to a *very short* stem which bears the ordinary green leaves.

**Mature Plant.**—In the mature plant of the first season's growth three zones exist, (*a*) root, (*b*) hypocotyl, (*c*) stem and leaves. The primary root persists and gives rise to a well defined, deeply penetrating tap-root which bears many branch roots, arranged in two longitudinal rows, diametrically opposed.

The hypocotyl also elongates with age until a certain limit is reached,

but it bears no branches. As growth continues the hypocotyl and upper part of the tap-root swell greatly and form that part popularly termed the root. Yet, evidently, this nomenclature is botanically inaccurate. The proportion of root to hypocotyl differs according to variety; in some cases, e.g. Globe, practically the whole of the hypocotyl exists above the ground, whilst in others, e.g. Long Red, it is drawn below the surface of the soil.

Microscopical examination of the swollen part shows that it serves as a storage organ for foods elaborated in the assimilating green tissues. It differs from the corresponding organ of the turnip in that there is a series—usually six or seven—of concentric rings of vascular tissue.

There is a wide variation in shape of the storage organ, which provides a suitable basis for classification into (*a*) *Long* varieties, possessed of more length than breadth; (*b*) *Intermediate*, or Gatepost types, which are oval; (*c*) *Tankards*, which are somewhat cylindrical; and (*d*) *Globes*, which are spherical.

**Stem and Leaves.**—The stem is exceedingly contracted and bears a profusion of leaves. The leaves are of a medium green hue, smooth surface, of a rather long ovate shape, and have a clearly defined leaf stalk.

**Second Year's Growth.**—In the second year, the short stem emerges into an erect branched one of about 3 ft. high, bearing many leaves and terminating in the floral system. This transformation drains the storage organ of its reserve of nutrients.

**The Floral System** (inflorescence) consists of a number of branched axes bearing at intervals along their length clusters of from three to seven flowers, which are subtended by small leaves, termed bracts. Each flower is very small and consists of (*a*) five little green leaves externally, collectively known as the perianth; (*b*) five stamens internal to (*a*); and (*c*) a one-celled ovary in the centre. The pollen from the stamens is shed before the ovary is ready for fertilization, and consequently cross-fertilization has to be relied upon.

In the maturing process following fertilization, the receptacles of the different flowers in each cluster become fused with each other, and produce a collection of fruits in one mass, each possessed of a single seed, as already explained.

The mangel is only intentionally allowed to run to seed under special circumstances. It is mainly cultivated with the object of utilizing the result of the first year's growth.

## Soil and Climate.

The mangel crop can be grown quite successfully on a wide range of soils, but the best crops are obtained from heavy loams. On the heavier clays, provided a good tilth is obtained in the spring to ensure a plant, fairly good crops can be grown, but the lighter sandy soils must be in

a high state of fertility and be well manured before good results can be expected from them.

A mild climate with plenty of sunshine is necessary; hence the crop can be successfully grown over the greater part of England and Wales and even in the south of Scotland. Farther north than this the climate is too cold. The mangel plant can stand drought better than it can stand cold and wet, but moderately dry seasons with plenty of sunshine are the conditions most favourable for its growth.

### Position in the Rotation.

The usual position of the mangel crop in a rotation is between two grain crops. It is not one of the best cleaning crops, but it is generally utilized for this purpose and thus occupies part of the root break. Where circumstances allow, the practice of growing mangels year after year continuously on the same land is a good one. If a field near the farm buildings is suitable it can be set aside for this purpose. By so doing, the labour of carting the roots to the buildings and the manure to the land is reduced. On account of the continuous necessary cultivations, the soil becomes very free from weeds of all kinds, and, through the annual application of farmyard manure, it also becomes very fertile, such conditions being ideal for the growth of the mangel crop.

### Autumn Cultivations.

To grow mangels successfully, strict attention must be given to the preparatory cultivation. The plant is deep rooted, and it is thus advisable that at least one of the ploughings should be deep to aerate the soil and allow the roots to penetrate it deeply. Where the land is foul it must be thoroughly cleaned before the seed is sown. Under suitable climatic conditions this can best be done in the autumn. Directly after harvest the land should be ploughed shallowly, and the roots of perennial weeds, such as Couch Grass (*Triticum repens*), worked out of the soil by cultivating and harrowing, when they are collected and burned. It is futile to attempt to grow mangels on land that is full of Couch, as the mangel plant is so weakly at the start of its growth that it is unable to compete with the Couch. After the roots of all weeds have been removed the further cultivations will depend entirely on whether the crop is to be grown on the flat or on the ridge.

On some of the heavier soils it is a common practice to ridge up the land in the autumn, apply the farmyard manure in the drills (or baulks), split the ridges back over the manure, and rely on the winter weathering to mellow down the furrows to a fine tilth. In the spring the ridges are harrowed down, earthed up again, and the seed sown on the fine mould thus obtained. On those soils such a fine mould would never be obtained by spring ploughing and subsequent cultivations.

On the lighter soils, and especially where the crop is to be grown on the flat, the farmyard manure is better applied in the autumn or early winter and ploughed in not too deeply. But in order to obtain the necessary depth of tilth, the land should be again ploughed more deeply in the spring. By doing this the manure becomes better distributed through the soil and also more decayed. Should it happen to be a dry summer, the addition of this organic matter helps greatly by retaining moisture in the soil for the growing crop.

Where farmyard manure is not available for application in the autumn or early winter, the land can be deeply ploughed, then cultivated again in the spring, and the farmyard manure applied before the last ploughing. Good crops can frequently be grown in this way, but there is always the danger that, in the event of an exceptionally dry summer, the manure, especially if it is not well rotted, may keep the soil too open.

### Spring Cultivations.

Whatever method of cultivation be followed, it is impossible to get the seed-bed for mangels too fine. This is effected by thoroughly cultivating and harrowing the land which has lain in furrows since the early part of the winter. Every precaution, however, must be taken not to work the land when it is too wet, and it is equally important to prevent its becoming too dry after it has been ploughed. To ensure the latter consideration, in dry weather it is always advisable to harrow and roll down at the end of each day that portion of the field which has been ploughed, when this cultivation has been introduced at this stage. If this be neglected no amount of harrowing and rolling can produce as fine a tilth afterwards.

Should the tilth not be quite as fine as desired, it is sometimes better to plough the land again than to attempt to reduce it by further surface cultivations. In deciding what cultivations to give his land, the farmer should be guided in great measure by his own experience, as no two fields have exactly the same soil, and every season differs in some respects from the one that preceded it.

After these preliminary cultivations have been effected, manuring and seeding are the next consideration.

### Manuring.

The mangel plant is a gross feeder, and, even on the richest soils, the crop will respond to liberal manuring. The basic dressing is generally farmyard manure, but even where fairly heavy dressings are applied they should be supplemented by a complete dressing of artificials. With an application of 20 tons of farmyard manure per acre, a suitable mixture of artificials would consist of from 2 to 4 cwt. superphosphate, 3 to 5 cwt. kainit, and 1 cwt. sulphate of ammonia. These can be safely mixed together and sown at the same time as the seed. After the plants have

been singled the crop should be top dressed with about 2 cwt. nitrate of soda or its equivalent in sulphate of ammonia. This should be applied in two dressings, the first shortly after singling and the second about three weeks later. If the application of the top dressing be delayed too long it may lessen the keeping properties of the roots; this is probably due to the nitrogen prolonging the growth and thus allowing the plant too little time for ripening.

In the above mixture the superphosphate may be wholly or partly substituted by steamed bone flour. Basic slag may also be used, but it cannot be used in a mixture with sulphate of ammonia, as ammonia gas would be given off and nitrogen consequently lost. If basic slag be used, it is often better to apply it during the winter, when the kainit may, with advantage, be mixed with it and applied at the same time. It is, however, not advisable to plough the land after these manures have been applied, as they would then be buried out of reach of the roots of the young plant. It should also be noted that heavier dressings are required than when the manure is applied directly in the drill in spring.

It is in the early stages of the growth of the plant that phosphates are most required, as they have a great effect in encouraging root development. Of the phosphatic manures available superphosphate is the quickest acting. On the stiffer soils, however, and on soils inclined to be acid, it may be advisable to use basic slag. Soil acidity does not seem to be injurious to the mangel plant, but in any scheme of manuring the effect of the manure on the texture of the soil and also on the health of succeeding crops in the rotation must be taken into consideration.

The potash in the manure mixture may be supplied from any of the various forms in which potash is put on the market, and when there is a big variation in the price per unit of potash the cheapest should be used. At the same time it is now recognized that potassium chloride (muriate of potash) is rather more effective than potassium sulphate. Kainit has an advantage over other potassic manures in that it contains a fairly high percentage of common salt, which encourages the growth of the mangel plants, thereby increasing the yield.

While farmyard manure is commonly used, good crops of mangels can be grown with artificials alone, provided that the soil is not too poor in condition. A mixture of 4 to 6 cwt. superphosphate, 5 to 8 cwt. kainit, and 1 cwt. sulphate of ammonia applied at the time of sowing, with several top dressings of nitrate of soda or other nitrogenous manure after singling, would produce a good crop. The crop which follows in the rotation would, however, suffer to some extent through the lack of the residual organic matter which would have resulted if farmyard manure had been applied.

**Methods of Applying the Manure.**—When the artificial manure is applied at the time of seeding, several methods of sowing are practised.

In the case of land that has been ridged, the manure is generally sown along the drills or over them by machine or by hand, and covered up by the earth thrown over by the plough on the ridges being split.

Where the crop is sown on the flat, some seed drills are fitted with a manure distributor which sows the manure in rows by means of coulters which run immediately in front of the seed coulters. This method has an advantage in that the seeding and manuring are performed at one operation, the manure being drilled in in front of and a little deeper than the seed. It is thus near to the roots of the young plants, so that the latter can make use of it as soon as they begin to grow. If, however, a large dressing of artificials is being applied, and the mixture contains a large proportion of kainit, the manure may prevent the germination of the seed or be injurious to the growing seedlings if the seed does germinate. Cases have been known to occur where crops have failed to grow on this account.

The safest method, when very heavy dressings are being given, is to sow the manures with an ordinary broadcast manure distributor, and harrow it in with seed harrows; the only objection to this method is that the manure naturally left between the rows may encourage the growth of annual weeds. Unless during exceptionally wet seasons these weeds can, however, be easily contended with, and as the mangel plants become larger their roots spread out and make use of the manure that has been deposited between the rows. The crop is thus gradually supplied during the whole growing season.

### Varieties of Mangel.

Mangels are usually classified according to the shape and colour of their roots. This classification includes Long Reds, Yellow Globes and Golden Globes, Red Intermediates and Yellow Intermediates, Golden Tankards and Yellow Tankards.[1]

The feeding value of mangels depends on the percentage of dry matter and sugar which the roots contain. The dry matter may vary from 8 per cent to 15 per cent, the Tankard varieties being the richest. Some seedsmen are introducing new varieties with a very much higher percentage of dry matter, but meantime as the percentage of dry matter is increased the yield per acre generally suffers.

The Long Red variety is only suitable for deep soils. It can stand dry seasons better than any other variety. It is also a large cropper, but has the disadvantages that the roots are difficult to pull, and on account of earth adhering to them they are rather dirty to handle.

Globe and Intermediate varieties are best adapted for most purposes,

[1] See another classification in COMPOSITION AND NUTRITIVE VALUE OF MANGOLDS, p. 140. Yellow Globe = White Fleshed Globe; Golden Globe = Yellow Fleshed Globe; Yellow Intermediate = White Fleshed Intermediate; Golden Tankard = Yellow Fleshed Tankard.

and are the most extensively grown. They produce a good crop of fair feeding value; they are easy to pull, and very little earth adheres to them.

The Tankard varieties can only be grown successfully on the best soils. They seldom produce such large crops as the other varieties, but where they can be grown their better feeding value more than compensates for any loss in bulk of crop.

In deciding which variety to grow, the farmer must take the local conditions of soil and climate into account as well as the invaluable experience of the past. It is easy to experiment with several different varieties and thus arrive at a conclusion as to which variety suits the conditions best.

### Time and Method of Sowing.

The time of sowing mangels varies with the different districts. In the eastern and midland counties of England they are sown from the second week in April till the beginning of May. In the southern counties they can be sown much later with quite good results. Crops sown as late as the beginning of June do quite well, provided that there is enough moisture in the soil to germinate the seed at once. In the southern counties of Scotland they are sown about the middle of May. If sown too early there is danger of the crop bolting, i.e. running to seed. This is believed to be due to the effect of frost on the young seedlings.

Mangel seed consists of what is botanically known as a " multiple fruit ", which really means that each seed contains two or more real seeds enclosed in a thick casing of rather hard husk. The actual seed is thus very small, and the young seedling that grows from it very delicate in the early stages of growth.

Mangel seed germinates slowly, and, in order to hasten germination, the seed may be soaked in water for about twelve hours, when it should be surface dried by spreading out thinly on a floor. This practice softens the husk and may be beneficial in a specially dry seed-time. There is always the danger, however, that the weather may change in the interval between the time of soaking and the time of sowing, with the result that if the sowing be unduly delayed the seed may germinate and be spoiled.

### Ridge System.

When grown on the ridge system the ridges should be made from 26 to 28 in. apart. The seed is sown with an ordinary ridge root drill which sows two ridges at a time. On account of the seed being so small, it is a mistake to sow it too deeply; at the same time in dry weather it must be deposited deep enough to obtain sufficient moisture to ensure germination and growth. From ½ in. to 1 in. in depth, according to the condition of the soil, is deep enough.

From 4 to 6 lb. of seed per acre are sown under the most favourable

conditions, but under less favourable conditions, as in Scotland, from 8 to 10 lb. are often sown per acre. It is a good practice to sow the seed on the same day as the ridges are made, or on the same day as they are earthed should they have been previously made in the autumn. The seed thus gets the benefit of the moisture in the freshly turned up soil before it has had time to get dried out. The ridges should be rolled down with a heavy ridge roller after sowing, as this helps to break any clods that may have been turned up, and, by consolidating the ridge, the young plants are better supplied with soil moisture, which is brought to the surface through increased capillary attraction.

### Flat System.

When the crop is grown on the flat the ground should be rolled before sowing. The seed is then sown with a drill that sows four or five rows at a time. It is usually fitted with a steerage arrangement, which makes it easier for the man operating it to run the rows straight. This is very important, as when the rows are straight it is much easier to horse-hoe them, better work is done, and there is less danger of cutting out the plants.

The depth of sowing varies from ½ in. to 1 in., and the quantity of seed from 6 to 8 lb. per acre. The seed drill is followed with a very light seed harrow, which levels the coulter marks and covers the seed properly. The width between the rows may be from 18 to 24 in. Where the rows are narrow a greater number of plants can be grown on the same area, but it does not give so much room for horse-hoeing, and plants are consequently more likely to be damaged or pulled out.

Where the land is clean, and where there is a likelihood of drought, sowing on the flat is certainly to be recommended. The great drawback, however, to this method is that nothing in the nature of horse-hoeing can be done until the plants are seen in rows. If there happens to be a lot of rain after sowing, annual weeds, such as Groundsel (*Senecio vulgaris*), Spurrey (*Spergula arvensis*), and Knotweed (*Polygonum aviculare*), when present grow very rapidly, and especially if a good fine tilth has been obtained for a seed-bed. These weeds may become thoroughly established before the mangel plant—which is rather slow-growing at first—is sufficiently high for horse-hoeing. In these circumstances what is known as flat hoeing has to be resorted to, that is, hoeing between the rows by hand. This adds considerably to the cost of labour on the crop.

### Horse-hoeing.

Under favourable conditions the young mangel plants should appear within a fortnight of the time of sowing, and should be ready for horse-hoeing in about other ten or fourteen days. It is very much easier to manage the growing crop and control the weeds when a quick braird and uniform plant is obtained.

When sown on the ridge, horse-hoeing can be done whenever any weeds appear. This is the great advantage of the ridge method of growing over the flat method. The best implement for use at this time is a light one-horse grubber which takes one drill at a time. The horse-hoeing can be continued whenever necessary right through the growing season until the mangel plants are too big to allow of this being done without damaging them.

When grown on the flat one must be able to see the plants in rows before the horse-hoe can be used. To obviate this difficulty a few oats are sometimes mixed with the mangel seed. The oat plants grow much more rapidly than the mangel plants and make the rows much more easily seen; horse-hoeing can thus be practised earlier. The oat plants can be easily hoed out when they have served their purpose.

The horse-hoe generally used takes two rows at a time, and consists of a series of horizontal blades fixed by upright shanks to a horizontal bar. These blades can be set so as to cut close to the rows of plants. It is advisable to have a boy to lead the horse, in order that the man in charge can devote the whole of his attention to guiding the implement. The blades should be held as near to the plants as possible without cutting them out or burying them, and when this operation is properly done it makes the work of singling much easier. If possible, the crop should be horse-hoed twice at an interval of a week before singling, and, after singling, at short intervals so long as it can be done without injuring the plants.

### Singling and Hoeing.

Singling should be commenced as soon as the plants are big enough to set out easily as single plants. The ease with which the operation can be done will depend greatly on the previous management of the crop. If the seeding has been too thick it is much more difficult to separate out the plants; if the land is full of Couch the plants are liable to be drawn out with the Couch; and if the horse-hoeing has been carelessly done the weeds will be troublesome to cut out.

The singling is done with a hand-hoe, and it is surprising how well an expert with the hoe can manipulate the tool. The plants should be left from 10 to 15 in. apart, care being taken to leave the strongest plants, to leave only single plants, and to cut out all weeds by the roots. Plants left in doubles and weeds cut off at the surface of the soil indicate very careless workmanship.

Where a large area of hoeing is to be done with a limited number of hands, it is a good plan to commence singling when the plants are rather small; otherwise those in the remainder of the field may be too large before the work is completed.

In about three weeks or a month after singling, the crop should be hoed again, any weeds that have grown in the interval removed, and any double plants that may have been left, singled. By this time the mangel plants should be covering the ground sufficiently with their leaves to prevent the further growth of weeds.

### Yield per Acre.

After every care has been taken with cultivation, manuring, horse-hoeing, and hand-hoeing, the ultimate crop will depend on the season. The mangel is a sun-loving plant, and, provided that the plant is once properly established, it will stand drought better than any other crop. In a dull wet season it will not produce as good a yield as in a moderately dry one with plenty of sunshine.

Phenomenal yields of over 100 tons per acre have been reported from small plots and from special manurial treatment, as, for example, where sewage is used, but in ordinary farming practice from 20 to 40 tons per acre according to soil, season, and manurial treatment should be considered quite satisfactory. As a rule larger yields are obtained in England than in Scotland, as the climatic conditions in England are more favourable.

### Insect Pests.

The mangel plant, like all others, is liable to be attacked by numerous insect pests, but, while the crop may be slightly damaged by these, it is seldom that it is completely ruined. The most virulent are the larvæ of the Mangel Fly (*Fegomyea betæ*) and the adult and larvæ of a beetle, *Plectroscelis concinna*, somewhat similar to the Turnip Flea Beetle. The former do not injure the crop to any great extent unless an attack is made when the plants are very small; no antidote is then very effective. The latter have become more troublesome of late, and may be counteracted by rolling the plants with a light roller while the dew is still on the leaves. Other pests include Wireworms, Leather Jackets, and Slugs. See Insect Enemies of Root and Potato Crops, p. 272.

### Fungoid Diseases.

These seldom do much damage to the mangel crop, as it is comparatively free from them.

The most pestilent is Heart Rot, which is most likely to occur in very dry seasons, when Globe varieties are more susceptible than Long Red and Intermediate varieties. No thorough preventive has yet been discovered, but, where the disease occurs, it is not advisable to grow mangels too frequently on the same land. See Diseases of Root and Potato Crops, p. 225.

**Harvesting.**

Unless the season has been very late and autumn growth rather prolonged, the mangel roots should be ready for pulling about the middle of October. The roots cannot stand frost to the same extent as swedes and turnips, and consequently they must be pulled and stored before they are likely to be damaged. In Scotland and the north of England it is on that account risky to delay the harvesting till after the end of October. In the south of England they should all be stored by the middle of November.

The method of pulling and storing varies according to localities. In some cases the mangels are pulled, the leaves simply twisted off by hand, and the roots thrown direct into the carts; in other cases the leaves are cut off with an ordinary trimming knife, the roots at the same time being left in rows wide enough to allow a cart to go between for picking up; in still other cases the roots are thrown into small heaps and the heaps are covered with the leaves that have been cut off.

On no account should the small rootlets be cut off, as, in doing so, there is always the danger of cutting the skin of the root, which greatly reduces its keeping properties.

In cutting off the leaves, care should also be taken not to cut them too closely to the crown as the keeping properties may be impaired in this way.

It will be found at this stage that the varieties that pull up without much earth adhering to them are much easier to pull and much cleaner to handle afterwards.

Of these three methods, that of making small heaps and covering with leaves is to be preferred, since the roots are thereby slightly protected from frost, and pulling can be commenced and continued even though the carting cannot be done at once; moreover, it is believed that the roots keep better by being left in the heap for upwards of a week before carting into the clamp. It means a little extra labour, but that is more than repaid by the better results.

Throughout the whole period of mangel pulling and carting there is always the danger of a severe night's frost, which may injure any unprotected roots. The roots that have not been pulled can stand a certain amount of frost, as can also those that have been put in small heaps and covered with leaves, but where they have been pulled and left in rows, it is advisable to have the carting close up to the pulling, so as to have as few as possible lying exposed each night. *If by chance any roots do get frosted, they should not be touched till the frost has gone right out of them.* To handle or cart roots into a clamp with any frost in them is fatal to their keeping properties. Such roots should be placed in a clamp separate from the rest, so that they may be used first.

**Storing.**

The value of the mangel crop is greatly enhanced by storing, if the keeping properties of the roots are good. Different varieties vary slightly in their keeping properties. The Long Reds and Tankards, which are rather richer in dry matter, keep better than the Globe and Intermediate varieties; with all the varieties, however, the keeping properties are greatly influenced by the methods of handling and storing adopted. It has been found that, if the ground and mangels are abnormally dry when pulled and carted, the roots do not keep so well as when they have been thoroughly saturated with water. This is rather contrary to what one would expect, but it may be due to exceptionally dry conditions inducing overheating in the clamp.

If mangels are pulled before they are properly ripe they are not likely to keep well, unless they are left in small heaps in the field to mature before carting.

In some districts the handling of the roots is done by forks. It is surprising how speedily they can be lifted in this way; but mangels handled thus do not keep well, and unless the roots are to be used early in the winter this should not be done. Injuries caused by the prongs of the forks induce decay, which readily extends to the centre of the root. It is better to throw them into the carts by hand and avoid as much as possible injuring the roots.

When choosing a site for the mangel clamp it is advisable to have it as near as possible to where the roots are to be consumed. This cannot always be done, as the distance may be too great to allow of the carting being done in the time available. In that case the clamp must be made nearer to the field in which the crop is grown. The roots have then to be brought to the buildings during the winter, when there is generally more time available. When this has to be done, it is always wise to have the clamp in some corner where it will not interfere with subsequent cultivations of the field, and also near to a roadway along which the mangels can be carted in all kinds of weather.

In districts liable to severe winters particular care has to be taken in making the mangel clamp and in providing a sufficient covering to protect the roots from frost. The clamp is usually made in the same form as a potato pit, but wider. From 6 to 8 ft. is a convenient width, and the roots are built up at the sides to form a ridge about 6 to 8 ft. high. The part of the clamp made each day should be covered over at night with a coating of straw to keep out any frost that may occur. When the clamp is finished a coating of about 6 in. of earth is placed over the straw, the earth being dug out from along the sides of the clamp, and the channel thus made round the clamp drains away any water that may collect, thereby keeping the bottom of the clamp dry. It is not advisable to put on the

covering of earth until the roots have stopped heating; in any case the coating of earth should not be carried right up to the ridge, but should stop at least a foot therefrom. This allows plenty of space for ventilation, and it is very rarely that the roots near the top of a clamp get frosted.

The clamp should be finished off all over with a thick coating of old straw, cavings, hedge trimmings, or any such roughage that is available. This acts as a further protection from frost, and, once it gets properly set, does not blow off readily.

In districts where the winters are not so severe it is not necessary to use a coating of earth as a covering. If a sufficient thickness of other material is put on it serves to protect the roots quite well and requires much less labour.

When the roots are to be consumed before late spring, they will keep quite well in a much bigger heap, and can be conveniently stored against a wall at the buildings or placed in a big square clamp. The bigger the clamp the less building of the roots is necessary, and it takes a much smaller amount of material to cover roots stored in one big clamp than it takes to cover the same number of roots stored in a number of smaller clamps.

In some cases the clamps are thatched to keep out the rain, but it is questionable whether they keep any better when this is done.

Where there is sufficient shed accommodation at the farm buildings, a certain proportion of the crop may be stored there. The roots keep quite well when stored in this way, and they require less covering to protect them from frost. In every case some of the roots should be stored near to the buildings, as these can always be used when it is not convenient to cart them in from the clamp farther away.

When harvesting and storing have been done properly the mangel roots should remain quite sound right on to the end of June; in fact they have been known to keep right up till the time the next season's crop has been ready for use.

### Utilization of the Crop.

The feeding value of mangels depends on the amount of dry digestible matter which the roots contain. Nearly two-thirds of the total dry matter is composed of sugar. Mangels have a further value in that they supply a succulent feed during the winter months when very little food of that nature is available. Compared with swedes they have only a slightly higher percentage of dry matter, but they keep much longer and can be fed throughout the spring and early summer after the swedes have all been consumed. They should, however, not be fed until about the middle of December, as, after being placed in the clamp, they undergo a further process of ripening. The dry matter undergoes a chemical change, the pectose and pectin being converted into soluble sugars and the amides

into albuminoids. If fed to any great extent before this change takes place, they are apt to cause scouring among stock.

The bulk of the mangels that are grown are fed mainly to cattle. In dairying districts favourable for their growth they are the principal root crop grown for dairy cows.

A daily ration of 60 to 80 lb. per cow may be fed with advantage, and they form a cheap source from which to build up the carbohydrates in the ration.

There are great differences of opinion as to whether they should be pulped or fed whole. Pulping does not increase their feeding value, but when the fodder in the ration is not very good it may be chaffed and mixed with the pulped roots. By doing this the cows may be induced to eat more of the inferior fodder. There is no doubt that cows seem to relish eating whole roots, and if all the other food in the ration is sweet and good, there seems little reason for going to all the labour and expense of chaffing the fodder and pulping the roots.

Mangels fed to dairy cows produce no bad effects on the quality of the dairy produce. They do not tend to taint the milk in the same way as turnips and swedes do, when fed in excess.

Young store cattle should not be given too many roots of any kind, but a few pounds of pulped mangels are greatly relished by calves about six months old. Those over one year and under two may be given up to 20 lb., and those over two and under three up to 40 lb. per day. For young cattle it is advisable and often necessary to pulp the mangels, as their teeth are not usually so strong as those of older cattle.

On feeding farms, mangels are largely used for fattening purposes, and as much as 112 lb. per day is quite commonly fed to large steers. Where such large rations of roots are fed, it is advisable to feed an adequate ration of concentrated foods or the animal will be unable to make full use of the carbohydrates in the root ration.

Mangels are not fed extensively to sheep. This may be largely due to the fact that the roots have to be carted and stored, which makes them quite unsuitable for consumption by sheep folded on the land. That they are a useful food for sheep goes without question, and in the spring of the year when grass is short a load of mangels carted out to the pastures each day to a flock of ewes with lambs will induce the ewes to produce more milk and brings the lambs on rapidly. If the supply can be continued while they are being folded on such catch crops as Winter Rye and Winter Vetches, the lambs soon learn to eat the mangels and do well on them.

There is a belief in some districts that mangels, if fed in large amounts to tup hoggs, will render the tups sterile, but there does not appear to be sufficient foundation for this assumption.

For horses there is nothing better than one or two mangels given

to them in the whole state after their day's work. When on hard winter feeding they keep their digestive system in proper order, thus preventing colics and other digestive troubles that are likely to appear at that time.

As a food for pigs they can only be fed in quantity after being boiled. They are not nearly so good as potatoes for this purpose, but when the latter are not available they are about the next best substitute.

For poultry, if there is a great scarcity of green stuff, mangels are sometimes used, and a whole mangel thrown into the runs is soon consumed by the fowls, and may carry them on until other green stuff is ready.

### Scope for Increased Production.

There is still plenty of room for improvement in the total yield of food per acre obtained from the mangel crop in this country, and no crop will respond more to intensive culture than the mangel crop. The percentage of dry matter might also be greatly increased in the different varieties by breeding and selection. The increase in the percentage of sugar in the root of the sugar beet plant since the sugar beet industries were started on the Continent points to the fact that a great deal might be done with the mangel plant as well, since it belongs to the same family of plants.

What the agriculturist requires is a mangel of even much higher feeding value than those now commonly grown, and one which will at the same time produce a large yield per acre.

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# COMPOSITION AND NUTRITIVE VALUE OF MANGOLDS[1]

By Professor T. B. WOOD, C.B.E., M.A., F.R.S.

### Individual Variation.

Analyses of large numbers of individual roots taken at random in the field, abnormally large and small roots being avoided, showed that the individual variation in composition is so great that at least fifty separate roots must be sampled in order to obtain a mixed sample representing, within the limits of the error of analysis, the average composition of the roots grown in a field.

[1] Most of the information contained in this article is derived from a comprehensive investigation on the chemical composition of mangolds by Wood and Berry published in the *Journal of Agricultural Science*, Vol. I, p. 176.

**Method of Sampling.**

The composition of a root is not the same throughout. The percentage of dry matter is higher on the outside of the root than in the centre. The percentage of sugar is also higher on the outside than in the centre, but its distribution differs from that of the dry matter, the crown of the root containing much dry matter but little sugar. The nitrogen is, on the whole, higher in the part of the root which lies under ground.

The method of sampling which is found most convenient is to take a core, by means of an instrument like a cheese-borer, through the greatest diameter of the root in a horizontal direction. Fifty roots are cored in this way, avoiding those which are abnormally large or small. The cores are wrapped in grease-proof paper, packed in a tin box, and sent to the laboratory for analysis.

**Composition of Roots.**

It is impossible to give average figures for the composition of mangolds, and even if it were possible the figure would be useless on account of the great difference between varieties. This variation, however, is regular and capable of classification as follows:

**Composition of Different Varieties.**—Chemical and botanical examination of the very large number of seedsmen's strains of mangolds shows that, with a few miscellaneous exceptions, all the strains can be included in the following five varieties.

*White-fleshed Globe.*—This variety produces large globe-shaped roots with white flesh. The skin is yellow below ground, shading to white or green above. The leaves are comparatively small and erect, very bright green with white or yellowish petioles. The strains of this variety are very vigorous, and produce heavy crops of large, well-shaped roots. In the series of investigations quoted above the average yield per acre was 30 tons, and the roots contained on the average 10·7 per cent of dry matter, 6·3 per cent of sugar, and 0·165 per cent of nitrogen.

*White-fleshed Intermediate.*—This variety produces roots which are longer and more spindle-shaped than that of the White-fleshed Globe. The skin is usually rather more yellow, and the flesh has a very faint yellow tinge. The various strains of this variety are less uniform than is the case with the White-fleshed Globes. The variety is rather less vigorous and grows a slightly smaller crop, but the roots contain rather a higher percentage of nutrients.

The average yield per acre in the investigations quoted above was $27\frac{1}{2}$ tons, and the roots contained on the average 12 per cent of dry matter, 7·1 per cent of sugar, and 0·168 per cent of nitrogen.

*Yellow-fleshed Tankard.*—The roots of this variety are of what is known as the tankard shape, but most strains produce a certain proportion of globe-shaped roots. The flesh is deep yellow in colour, the skin

shades from crimson on the underground portion to yellow near the crown. The leaves are larger and deeper green than in the white-fleshed varieties. The leaf-stalks are usually orange. This variety is not nearly so vigorous as the white-fleshed varieties. The average yield in the above quoted investigations was 24½ tons per acre, and the roots contained on the average 13·1 per cent of dry matter, 8·0 per cent of sugar, and 0·186 per cent of nitrogen.

*Yellow-fleshed Globe.*—This variety is similar to Yellow-fleshed Tankard in every respect except the shape of the roots. Most strains produce a considerable proportion of tankard-shaped roots. The average yield in the investigations quoted above was 25 tons per acre, and the roots contained on the average 13·4 per cent of dry matter, 8·2 per cent of sugar, and 0·191 per cent of nitrogen.

*Long Red.*—In this variety the roots are long and spindle-shaped, the skin being crimson or magenta underground, shading to brown near the crown. The flesh is pink. The leaves are erect and dark green with pink or crimson leaf-stalks. Long Red is a vigorous variety which grows heavy crops on suitable soil. In the investigations quoted above the average yield was 30 tons per acre, the roots containing 13·1 per cent of dry matter 7·9 per cent of sugar, and 0·157 per cent of nitrogen.

The above five varieties include nearly all the strains advertised by the seed trade, but there are in addition a few varieties which cannot be included in such a classification. Among these are Long Yellow, which resembles Long Red except in colour and in being a smaller cropper, Crimson Tankard, which is very similar to Golden Tankard in all characters except colour, and a few other varieties, among which may be mentioned several new varieties which are stated to be crosses with the sugar beet.

The more important figures relating to the five main varieties are collected for convenience of reference in the following table:

| Name of Variety. | Yield per Acre. | Dry Matter. | Sugar. | Nitrogen. | Dry Matter per Acre. | Sugar per Acre. | Nitrogen per Acre. |
|---|---|---|---|---|---|---|---|
| | Tons. | Per cent. | Per cent. | Per cent. | Tons. | Tons. | Lb. |
| White-fleshed Globe .. | 30 | 10·7 | 6·3 | 0·165 | 3·20 | 1·88 | 111 |
| White-fleshed Intermediate | 27½ | 12·0 | 7·1 | 0·168 | 3·29 | 1·94 | 103 |
| Yellow-fleshed Tankard .. | 24½ | 13·1 | 8·0 | 0·186 | 3·22 | 1·96 | 102 |
| Yellow-fleshed Globe .. | 25 | 13·4 | 8·2 | 0·181 | 3·35 | 2·05 | 107 |
| Long Red .. | 30 | 13·1 | 7·9 | 0·157 | 3·92 | 2·36 | 105 |

The figures in the table refer only to one set of experiments carried out in the eastern counties. The experiments, however, extended over three years, and were carried out at seven different stations, and the results are based on the analyses of six hundred separate samples.

They show that the larger cropping varieties contain less dry matter and sugar except Long Red, and that all the Globes, Intermediates, and Tankards yield the same amount of dry matter and sugar per acre, Long Red again being an exception, producing 20 per cent more dry matter and 18 per cent more sugar per acre than the other varieties.

From the point of view of the amount of food produced on a given area Long Red is no doubt the best variety to grow. It has, however, certain disadvantages. For instance, it does not suit all soils, and since it buries itself more deeply in the ground than the Globes and Tankards it is more troublesome and expensive to lift. Long Red is also quite distinct from other varieties in the composition of its dry matter, which contains a considerably smaller proportion of nitrogen.

**Composition of Roots of Various Sizes.**—It has long been known that the percentage of dry matter in roots is greater in small roots than in large ones. During the course of the investigation above referred to, many figures were obtained bearing on this point. These figures are summarized in the annexed table.

| Weight of root increases from Lb. | to Lb. | Percentage dry matter decreases by |
|---|---|---|
| 1 | 2 | 0·9 |
| 2 | 3 | 0·7 |
| 3 | 4 | 0·6 |
| 4 | 5 | 0·4 |
| 5 | 6 | 0·3 |
| 6 | 7 | 0·2 |

It will be noticed that up to 4 or 5 lb. increased size of root produces a large decrease in percentage of dry matter. Above 5 lb. the decrease in percentage of dry matter with further increased size of root is very much smaller. As no one expects to grow mangolds the average weight of which is less than 4 or 5 lb., the effect of the variation in dry matter with size of root is not of very great practical importance.

**Composition in Different Seasons.**—A study of the composition of the roots on the Rothamsted permanent mangold plots shows that broadly speaking a season which produces a large crop produces also roots with a low dry-matter content. But this is not always the case. In some exceptional years, e.g. 1895 and 1887, a cold wet sunless summer produced a small crop with low dry matter content or a hot dry summer produced a fairly large crop rich in dry matter. The ideal season appears to be warm showery weather in the early summer to ensure a plant and

good early growth, sun and occasional rain up to September, and a hot dry autumn for ripening. Seasonal variation may be very great. The limits on the dung, superphosphate, and nitrate plot at Rothamsted are from 8·8 per cent dry matter in 1895 to 15·4 per cent in 1887. Seasonal variation in ordinary farm practice is, however, not likely to exceed 1 or 2 per cent dry matter.

**Composition as Affected by Manuring.**—The amount of information on this point is not very extensive. Figures bearing on the point can be extracted from the Rothamsted memoranda and others from the Cambridge investigation. Broadly speaking, the figures show that any manuring which increases the crop at the same time decreases the proportion of dry matter and sugar. This is especially the case with manures supplying large quantities of nitrogen.

**Composition as Affected by Soil.**—On this point, again, precise information is somewhat scanty. As far as it goes the information available indicates that the variation in composition of mangolds grown on different soils is to be explained entirely by the fact that some soils grow large roots and others small ones.

**Composition and Nutritive Value.**—A separate investigation was carried out at Cambridge on this point, the results of which were published in the *Journal of Agricultural Science*, Vol. III, p. 225. The investigation dealt with the subject under three heads. A series of seven experiments carried out in three years on seventy-four animals showed conclusively that in the case of full-grown fattening cattle the nutritive value of Long Red mangolds was 16 per cent greater than that of White-fleshed Globe mangolds. This agrees well with the relative percentages of dry matter in these two varieties, which in the case of the samples used in the experiments was 11·8 per cent and 9·8 per cent respectively.

A second series of experiments showed that the nutritive values of Long Red mangolds and Golden Tankard mangolds were practically identical, the latter being if anything slightly the higher of the two. This again agrees with the relative percentages of dry matter, which were 13·1 per cent and 13·4 per cent respectively. The general conclusion reached was that the percentage of dry matter was a fair measure of nutritive value.

A third trial, the results of which were, however, inconclusive, seemed to indicate that for maintaining store cattle this conclusion did not hold, the reason suggested being that with the low protein ration of the stores the extra nitrogen of the mangolds, which were poor in dry matter, gave them a special value.

It will be realized from the above statements that the composition of mangolds is liable to so many causes of variation that it is impossible to give figures of any value for their average composition. Certain general

remarks may, however, be useful. The best index of the relative feeding value of different samples of mangolds appears to be the percentage of dry matter. The dry matter of different samples does not vary widely in composition. The percentage of sugar in the dry matter, for instance, seldom falls below 59 per cent and seldom rises above 61 per cent. It may, without appreciable error, be taken as 60 per cent.

The sugar contained in mangolds up to January or thereabouts appears to be almost entirely cane sugar, with a small proportion—not more than about 0·5 per cent—of some other dextrorotatory sugar, not readily inverted by hydrochloric acid. After January the cane sugar begins to be inverted, and the rate of inversion increases as the weather gets warmer. Inversion, however, does not decrease the nutritive value.

Sugar is not the only carbohydrate contained in mangolds; it forms indeed only about three-quarters of the total carbohydrate, the other quarter consisting of a gum-like substance known as pectin (which is sometimes called fruit jelly), and organic acids are also probably included as carbohydrates by the method of analysis commonly used.

The amount of fibre is very small, being only about 0·7 or 0·8 per cent in the root, or 6 to 8 per cent of the total dry matter. The total amount of nitrogenous compounds in mangolds is only about 1 per cent in the roots or 8 to 9 per cent in the dry matter. Of this only about 0·1 per cent in the roots is digestible true protein, the remainder being nitrate and a mixture of several amides. Among these may be mentioned glutamin, which is the most abundant, betain, and asparagin. Betain appears to be excreted unchanged in the urine and consequently has no feeding value. Glutamin and asparagin are oxidized in the body, and certainly provide a small amount of heat—about half as much as an equal weight of starch. Their nitrogen may have a protein-sparing value under certain conditions.

Changes take place in the nitrogenous compounds of mangolds on storage. The nitrate, for instance, disappears after Christmas, and, as nitrate is a toxic substance, this may account to some extent for the general opinion that mangolds are more wholesome food in the spring than in the autumn.

The amount of fat in mangolds is so small and so little is known about it that no comment is necessary.

The table on p. 146 gives approximate figures for the composition and nutritive value of each of the typical strains of mangolds. The figures are derived from average-sized roots grown under normal conditions. From these figures the average production starch equivalent should be as follows: White-fleshed Globe 5·5, Intermediate 6·2, Yellow-fleshed Globe or Tankard 6·8, Long Red 6·8.

In using mangolds it should not be forgotten that they form a highly

COMPOSITION OF DIFFERENT VARIETIES OF MANGOLDS

| Name of Variety. | Percentage Composition. | | | | | | Percentage Digestible Nutrients. | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Water. | Protein. | Oil. | Carbohydrates. | Fibre. | Ash. | Protein. Crude. | Protein. Pure. | Carbohydrates. | Fibre. |
| White-fleshed Globe .. | 89·3 | 1·0 | 0·1 | 8·2 | 0·7 | 0·7 | 0·7 | 0·1 | 7·5 | 0·2 |
| Intermediate .. | 88·0 | 1·0 | 0·1 | 9·4 | 0·7 | 0·8 | 0·7 | 0·1 | 8·5 | 0·3 |
| Yellow-fleshed Globe or Tankard .. .. | 86·8 | 1·2 | 0·1 | 10·3 | 0·8 | 0·9 | 0·7 | 0·1 | 9·5 | 0·3 |
| Long Red .. | 86·9 | 1·0 | 0·1 | 10·3 | 0·8 | 0·9 | 0·7 | 0·1 | 9·5 | 0·3 |

digestible and productive food for animals of all kinds. Their dry matter has approximately the following composition:

| | Percentage. |
|---|---|
| Crude protein .. .. .. .. | 8 |
| Oil .. .. .. .. .. | 1 |
| Carbohydrates[1] .. .. .. .. | 80 |
| Fibre .. .. .. .. .. | 6 |
| Ash .. .. .. .. .. | 5 |
| | 100 |

This makes it evident that mangolds are really a most digestible and productive food. They are certainly bulky because of their high percentage of water, but this is not a disadvantage in winter feeding.

They are most commonly used for fattening cattle in the winter, the ration varying from ½ cwt. to three times that amount. The larger ration together with straw provides sufficient bulk and energy value for full-grown bullocks. It is, however, somewhat laxative and at the same time rather deficient in protein. Both these defects can be remedied by the addition of 1 to 1½ lb. of common cotton cake per head per day. Experiments recently published in the *Journal of the Board of Agriculture* show that such a ration is both economical and successful in the production of winter-fed beef.

Mangolds are also largely and successfully used for feeding milch cows in winter, the ration in general use being from ½ to 1 cwt. per head per day. During the War they were also used successfully for feeding pigs.

They may also be used for sheep, but they will not stand frost, and are therefore not suitable for folding in the winter. The writer has, however, seen sheep folded on mangolds in September and October on the farm of a successful and progressive farmer, who stated that such was his usual practice.

[1] Including sugar 60 per cent.

# THE SUGAR BEET CROP

## By R. N. DOWLING, N.D.A.

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The manufacture of sugar from beet was started as a serious business in this country at a factory erected at Cantley, in Norfolk, in 1911, and this has been seconded by another at Kelham, near Newark-on-Trent. At the latter the first sugar campaign, as its working period has been called, was carried out during the winter 1921–2, the comparatively small quantity of 26,000 tons of sugar beet grown on 425 farms in the neighbouring counties being dealt with.

Few people have any idea of the enormous economic importance of the sugar beet industry. During 1921 these two factories dealt with 66,500 tons of sugar beet, the product of 7937 ac., from which 6363 tons of white sugar were manufactured. Nearly 5000 tons of dried slices, or the residual dried pulp from the roots after sugar extraction, were sold back to farmers as food for stock, besides treacle, &c. The above is not nearly the full capacity of output. The sugar realized something like £290,000. The carriage charges paid to the railway companies for beet amounted to £28,432, and in addition there were large sums for road and water transport. The factory wage bill was £43,314, and it is estimated that some £63,500 was expended on the labour connected with the cultivation of the crop.

Prior to the Great War every country in Europe possessed factories. Germany had 342, Russia 294, Austria-Hungary 201, France 224, Denmark 9, while Great Britain had only 1.

America had 77, but in 1917 14 new factories, each having a daily capacity of about 11,000 tons, were added to the list.

When one considers that America can only produce one-fifth of the sugar she requires for home consumption, and that we are importers of practically every pound of sugar used in this country, there would appear to be great scope for future development.

The successful establishment of the industry in this country entirely

depends on certain economic factors which cannot be discussed here. Let it suffice that, in view of the labour employed, the great quantities of beet, coal, limestone, &c., that demand transport, the general improvement of farming, and the yields of crops that follow the introduction of the industry and last, but not least, the fact that it is an industry so closely related with actual production from our own land, giving the farmers another saleable crop and the country another source of wealth, it certainly should be encouraged in every possible way.

### The Sugar Beet Plant.

The sugar beet is a variety of the same species as the mangold (*Beta vulgaris*). It is well to remember this, and that the characteristics, manurial requirements, cultivations, and general treatment of the two crops are somewhat alike.

Sugar beet, like the mangold, is a biennial plant, i.e. it ordinarily takes two years to produce seed. It is a tap-rooted plant, sending down a long straight root similar to a parsnip, but growing to a great depth and having an extensive root system. It is this habit of growth which brings about a natural breaking up or subsoiling of the lower layers of the soil, and which is partially responsible for the increased yields of other crops which follow in the rotation.

The sugar content of a typical beet crop can vary from about 15 per cent up to as much as 20 per cent. Numerous crops have been grown in England with 18 to 20 per cent sugar and a coefficient of purity of over 90 per cent, and this latter fact is very important from the factory point of view.

The beets vary in weight from 1 to 2 lb. each, but the average weight of fair roots is about 1½ lb.

### Soils Suitable for Beet.

The ideal sugar beet soil is a good, deep, free-working loam, free from stones, having " body ", but not being too stiff to make it difficult to get the crop up at lifting time. These conditions are by no means a *sine qua non*, however, and in fact are rarely found over such an extensive area as is necessary for the growth of sufficient beet for a normal-sized factory; for example, the author has seen beets grown for factory purposes on the chalk loams of the north of France, on the light sandy loams in Germany, and on some strong clay loams in Holland.

Successful crops were grown for the Kelham factory, near Newark, in 1921, on practically every class of land, from light sandy loams with gravel to quite heavy clay loams. The lighter classes of soils that have been dressed with lime or that have a natural lime content will generally give a higher percentage of sugar in the roots; and as nearly all factories work on a bonus on sugar system, this helps to bring the light cropping

land into line with some of the heavier yielding and stronger soils, although this is by no means always the case, as many heavy cropping soils will also produce roots of high sugar content.

### Climatic Conditions.

While it is generally conceded that the sugar beet is a lover of plenty of sunshine, it has been definitely proved that good crops having a high sugar content can be produced in most parts of this country in any year. Contrary to expectations the average percentages of sugar in beet grown during the wonderful summer of 1921 did not prove to be better than those obtained in ten different counties in England during the disastrously wet summer of 1912; and the latter results were obtained from crops grown in the west of England as well as in the east and south.

The 1921 crops showed a high sugar analysis up to the time when the first rains came in August, when second growth of leaves started, resulting in an immediate fall in the sugar content. This fact is mentioned to show that the sugar content is susceptible to climatic variations which are sudden or abnormal.

We have grown sugar beet successfully in Yorkshire, and in practically every county south of that, and there is little doubt that under fairly normal conditions as regards elevation and soil it would be successful farther north, and even in Scotland, where drilling could be carried out in April or early in May, and harvesting from the end of September to the middle of October. The crop is not so susceptible as mangolds to damage from frosts, the root being practically all buried like the root of a parsnip, and the very extensive foliage or top acting as a protection.

### Varieties of Seed.

The sugar beet has been very greatly improved during the past decade by means of careful selection and crossing. In most of the larger producing countries, prominent firms have specialized in scientific propagation for the production of seed which will give rise to beet of high sugar content and of good cropping capacity. Most firms possess pedigree stocks of seed, and can generally recommend a type suitable for the climatic conditions.

It is usual for the factory authorities to obtain large quantities of seed from the special seed-growers and distribute this to the farmers who have contracted to grow beet for the factory.

### Place in Rotation.

Sugar beet generally takes the place of a portion of the ordinary root crop, and in consequence of its being a cleaning crop which receives a liberal dressing of manures it prepares the land for subsequent crops in the rotation. It can, however, with advantage follow an ordinary root or potato crop, or it may come after clover leys or beans and peas.

### Autumn Cultivations.

If it is to follow a corn crop, it is a good plan to drag or cultivate the stubbles as deeply as possible, then harrow, and collect and burn any weeds. This work should be carried out as soon after harvest as possible, and if a steam or tractor cultivator can be set to cultivate as deep as 10 in., so much the better.

A dressing of 10 to 15 tons of farmyard manure per acre should be applied and ploughed in deeply. This deep autumn ploughing is of the very greatest importance, and has a very material influence on the yield of the crop.

Autumn dunging is much to be preferred to spring applications, because fresh manure causes fanginess and coarseness of the roots. It may even be advantageous to dung the preceding crop.

If the land has not usually been ploughed deeply and there is a plough pan present, then it may be advisable to subsoil. The subsoiling is done by a subsoiler which follows directly behind the plough in the open furrow; it can also be done by a subsoiling attachment to the plough or by another plough with the mould board removed.

A greater depth of worked soil is required for sugar beet than for mangolds, because the beet root should grow like a well shaped parsnip, and if it meets with resistance in the shape of a hard plough pan or unworked soil it will become fangy; this makes the root unsatisfactory from the factory point of view, both as regards sugar content and the working up of the root.

Fangy roots are often the cause of the high percentage of tare, and such condition is generally due to insufficient depth of worked soil. The tare is the amount of dirt to be deducted after washing the roots at the factory; generally it is about 10 to 15 per cent, but it may, with fangy roots, amount to 30 per cent or even more.

In the course of time ploughing in the sugar beet areas tends to get deeper and we have a greater depth of worked soil; this is largely responsible for the increased yields of other crops that follow sugar beet.

### Spring Cultivations.

These consist of the various operations usually carried out to reduce the land to a good tilth or produce a fine seed-bed. For example, a drag is sent over, followed by harrows. It may then be advisable to use the Cambridge roller to break down any clods, then give another harrowing, followed by a flat roll to consolidate and make the land ready for drilling.

Ridging should not be adopted unless the district is subject to heavy rainfall, and even then it should be avoided if possible. The reason is that roots grown on the ridge are almost sure to have too much of the upper part of the root out of the soil, and such is of no value to the factory

and has therefore to be topped with the leaves before the beet is sent in to the factory. If this is not done the factory authorities will remove and treat the green tops as tare, to be deducted from the weight ranking for payment.

Whatever methods of cultivation are carried out before drilling, it is essential that nothing should be done to destroy or bury the frost mould obtained from the winter ploughing. In view thereof spring ploughing is objectionable and should be avoided.

## Manuring.

Sugar beet likes a neutral or non-acid condition in the soil, and it will not thrive on soils suffering from shortage of lime and where sour conditions prevail. Further, it removes quite an appreciable quantity of lime from the soil, but the sourness arising from this cause is counteracted on the Continent by the return of the waste factory lime to farmers at a very small cost. This, however, is only justified where back cartage can be carried out, or where the lime has been dried out thoroughly; otherwise it would generally be cheaper and better to buy ordinary lump lime.

The calcium carbonate content varies so much that it is hardly possible to give a typical analysis of the so-called waste factory lime; it may vary from 20 per cent to 60 per cent or even more of lime as calcium carbonate.

The following are analyses of waste factory lime at the Kelham factory, Newark, after the 1921–2 campaign.

ANALYSIS OF WASTE LIME TAKEN STRAIGHT FROM SETTLING PITS

| | Percentage. |
|---|---|
| Moisture .. .. .. .. | 54·54 |
| Free lime (calcium hydrate) .. | 5·05 |
| Calcium carbonate .. .. | 36·47 |
| Organic matter .. .. .. | 3·94 |
| | 100·00 |

The amount of water present makes the above waste lime quite unsuitable for ordinary use.

ANALYSIS OF SAME WASTE LIME AFTER EXPOSURE TO AIR FOR THREE TO FOUR WEEKS

| | Percentage. |
|---|---|
| Moisture .. .. .. .. | 33·55 |
| Free lime (calcium hydrate) .. | 5·47 |
| Calcium carbonate .. .. .. | 52·39 |
| Organic matter, &c. .. .. | 8·59 |
| | 100·00 |

When dried to this extent the waste lime is in quite good condition

for handling and for application, and about 3000 tons were sold at 6*s*. per ton ex works.

Before considering actual manurial dressings, a study of the following data worked out by American investigators will be found helpful.

MANURIAL INGREDIENTS REMOVED FROM THE SOIL

| Crop. | Yield per Acre. | Nitrogen. | Potash. | Phosphoric Acid. |
|---|---|---|---|---|
| Sugar beet .. | 10 tons | 30 lb. | 70·0 lb. | 14·0 lb. |
| Potatoes .. | 6 " | 47 " | 76·5 " | 21·5 " |
| Wheat .. | 30 bus. | 48 " | 28·8 " | 21·1 " |
| Barley .. | 40 " | 48 " | 35·7 " | 20·7 " |

It will be seen that, like potatoes, sugar beets are lovers of potash. The crop responds to liberal dressings of potash manures, and these affect the consequent sugar content to a marked degree, as well as the yield per acre.

Although nitrogen is required to get a bulky crop, care must be taken not to overdo the dressings of nitrogenous manures, as otherwise too much leaf will be formed, to the detriment of the sugar content of the roots. Such manures, however, if judiciously used assist the deep rooting nature of the plant, and thus help it to resist drought. They also induce healthy leaf formation, and as the sugar is manufactured in the leaves before being transferred to the roots, it will be seen that healthy foliage is a point to be aimed at; excess of nitrogen, however, will cause late ripening, which is very undesirable.

While beet can do with a liberal application of artificial manure, it is undesirable to apply more than 15 tons of farmyard manure. In fact if the land is in fair condition, 10 tons supplemented by a suitable dressing of artificials is far better than very heavy dressings of dung, because such cause fanginess in the same way as is well known to carrot growers. It is further important for the same reason that the dung be either ploughed in during the autumn or winter or applied to the preceding crop.

TYPICAL DRESSINGS PER ACRE

1. *For light soils deficient in potash, e.g. sandy loams.*—

10 tons farmyard manure.
2 cwt. superphosphate (30 per cent).
2 cwt. steamed bone flour.
1½ cwt. muriate or sulphate of potash (50 per cent $K_2O$), or the equivalent of other potash manures such as potash salts or kainit.
1 cwt. sulphate of ammonia.

If muriate or sulphate of potash be used, an additional dressing of 3 cwt. common salt per acre should be given; with kainit or 20 per cent potash salts this is unnecessary.

The above artificials can be mixed and applied broadcast before the last harrowing.

In addition, top dressings of from 1 to 2 cwt. of nitrate of soda or nitrate of lime can be applied in two or even three dressings, the first to be applied immediately after singling, and the remainder at intervals of two weeks. It is very important to top dress immediately after singling to stimulate early growth and prevent a check from wireworm or other cause.

2. *For heavy and good-bodied loams.*—Such soils will probably contain more potash, and if lime is used at intervals, some of the potash will become available for the crops; the potash dressing can, therefore, be reduced to about half. On such soils the other manures can also be reduced with economic advantage.

On strong land, salt should be omitted if it is inclined to make the land soapy or of bad texture. On such land basic slag can be applied early to take the place of superphosphate and steamed bone flour, or a dressing say of 3 cwt. slag can be applied early, and later a smaller dressing of the mixed phosphates.

### Seeding.

From 10 to 20 lb. of seed per acre are drilled in on the flat, the average amount being about 15 or 16 lb. Drilling should not be on the ridge, because, as already stated, it produces roots with too much top out of the ground. The seed should not be buried to a greater depth than $\frac{3}{4}$ in.; the distance between the rows should be about 16 to 18 in., according to the drill available. It is important that good seed having a well known history be used, as inferior qualities produce roots of a low sugar content.

The time of drilling is about the same as for mangolds, namely, April or early in May. Too early drilling, if followed by cold weather and a check, causes bolting of the plants later on.

A mangold drill, if not too wide between the rows, can be used for sowing sugar beet. Other drills in ordinary use can often be quite well adapted for sowing sugar beet by shutting off the intervening coulters.

### Rolling.

It is essential that the soil should be firmly pressed round the seed, and to obtain this condition rolling should be resorted to after the seed has been drilled in.

### Hoeing and Singling.

The horse-hoeing should be started at the earliest possible date, and repeated several times during the growth of the crop. Hand-

hoeing should also be done as early as possible, and the plants singled out to a width of from 8 to 9 in., care being taken that no doubles are left in the row. Hoes with 7-in. blades are generally used.

If singling is not done early, the tap-root formation of the plant makes it very difficult to carry out efficiently, and results in bad and very expensive singling.

The prevailing system in England of singling by means of the hoe is a mistake, and is responsible for gaps, malformed roots, and lower yields. The Continental system of singling by hand is far better, but our labour conditions make it well nigh impossible to get it done here as cheaply as it is done abroad.

In singling by hand, what is known as bunching is previously done with a hoe. Thereafter the best plant in the bunch is quickly selected; two left-hand fingers are used to protect it, one being placed on each side; the other plants are pulled away with the right hand, and then the soil is pressed round the remaining plant by means of the two fingers of the left hand that were used to protect it.

If singling is done with a hoe, the greatest possible care must be taken, as faulty work combined with lateness can, as has been clearly proved by careful experiments, easily reduce the yield by tons per acre.

The benefits from horse-hoeing are very great, and if the horse-hoeing operations are carried out early, continually, and thoroughly, the crop will undoubtedly be enhanced, both as regards quantity and quality. The vital importance of hoeing has been clearly demonstrated by numerous experiments. Knauer and Hollrung showed that one hoeing gave 6 tons per acre, two hoeings $7\frac{1}{4}$ tons, three hoeings $9\frac{1}{4}$ tons, four hoeings $11\frac{1}{4}$ tons, and five hoeings $11\frac{3}{4}$ tons per acre.

It is probable that the small yields recorded in many instances where farmers have grown sugar beet in this country have been due to a great extent to improper hoeing.

Horse-hoeing not only cleans the land but it ensures a nice tilth on the surface, and such a condition prevents evaporation of the soil water and thus helps the plants to resist drought. It also helps to promote free entrance of air and warmth to the soil, which are very beneficial in assisting bacterial action and speeding up nitrate formation. Horse- and hand-hoeing should be continued as long as the plants will allow, but care must be taken to see that the soil is drawn to the plants and not away from them.

The Continental horse-hoes used for the beet crop are fitted with the usual A- or V-shaped shares of L-shaped blades, and do five rows at a time.

### Harvesting.

The time to start lifting the sugar beet can be told by the yellowing

or browning off of the lower leaves. Confirmation as to the crop being ready for lifting can be got from analysis for sugar content and purity.

October is the month when lifting is in full swing, but it may be possible to make a start at the end of September in some seasons.

The sugar beet is deep rooting and difficult to pull up, and special lifting ploughs are generally employed. These are either of the prong type so largely used on the Continent, or a kind of plough that runs alongside the row and practically pushes the beet with an upward movement, thereby making it possible easily to pull out the roots by hand. This latter implement is used largely in Canada and America. It is both efficient and cheap, and a number were sold to farmers who grew beet for the Kelham factory in 1922.

Another method that can be adopted with tractors or steam tackle is to use an ordinary cultivator with the tines arranged to run up between the rows of beet and close to the plants. This plan has worked well in large fields, and where there are large areas it is of great assistance in getting the work done quickly.

It is possible to run an ordinary plough up alongside a row of beet and turn a small furrow away, thus loosening the roots. One can also remove the mould board and run the plough point close to the roots and loosen them in that way. On the whole, however, it is best to have a proper implement for the work, as it is more efficient and quicker and will soon repay its cost.

After loosening the earth the roots are pulled by hand in pairs and knocked against each other to remove as much soil as possible. They are then laid in rows or heaps ready for topping. The top should be cut off cleanly immediately below the neck, and if not carted at once the roots should be covered with leaves, as their sugar content is reduced on exposure to frost or sun.

Hand prong forks and special little digger spades are used in Holland and in some other parts of the Continent, but this method demands a plentiful supply of cheap labour and is not so suitable for our conditions, although really the most efficient method.

The average yield of washed and topped roots is from 8 to 12 tons, though in some districts, such as the Fens, it may rise to from 14 to 18 tons per acre.

### Tare from Beet.

This is the term given to soil sent in with the roots, and to the waste tops that have no value for sugar purposes, and which should have been chopped off with the leaves in the field. The amount of tare is carefully determined with every consignment that comes in, and is deducted from the total tonnage delivered by the farmer. All deliveries are also tested for sugar content and purity.

The tare, of course, varies in strong and light land crops, and also in wet and dry seasons, but it also varies greatly on farms under like conditions according to the care taken. The average tare for the Kelham factory last season was 10·4 per cent. This is very low, as it often reaches 15 to 25 per cent, and may be even higher in bad seasons or where faulty roots are grown.

### Leaves and Tops.

The leaves and tops are very heavy and make good keep for stock turned in to consume them; they also make a good manurial dressing if ploughed in. On the Continent it is usual to cart the leaves and tops off, and to make silage by putting them into clamps or pits together with the wet slices, but if this practice is carried out it will be even more necessary to lime the land from time to time.

### Sugar Beet Pulp or Slices.

As regards these, the Continental method in the case of farmers who live near is to load back, after delivering beet, with wet slices or residual pulp. The pulp is put into pits or clamps in alternate layers 2 to 3 ft. deep, with the leaves and tops, the whole being consolidated by carts drawn over, and then finally covered with soil to a depth of 1 to 2 ft.

If properly made this silage will keep for two years or even longer, or, if required, it can be used after a few months. It is necessary to ventilate the clamps as with mangolds; also to allow drainage water to escape.

Special plant for drying the slices have been installed in the two English factories. The dried slices or dried pulp form a very valuable feeding stuff which will satisfactorily and entirely take the place of ordinary mangolds or other roots for feeding to all classes of stock on a basis of about 1 lb. of dried slices to 8 lb. of mangolds.

It has been stated by misinformed people that sugar beet culture might reduce the stock-keeping capacity of the farm. As a matter of fact every class of stock is kept in all sugar beet growing areas. On the Kelham factory estate a large milking herd of cows has been established and these receive dried slices in their daily ration. A large flock of ewes and other classes of stock are also kept, and instead of any reduction in the head of stock the reverse is the case both on the estate referred to and on many farms on the Continent.

In the sugar beet areas of Germany and Austria no other root-stuff besides beet slices is used for feeding to cattle, but in Holland and some parts of France mangolds are fed in conjunction with the pulp.

The following are actual daily rations fed on a typical dairy farm in Germany where 200 cows are kept:

*Cows in milk.*

8 lb. dried sugar beet pulp.
8 lb. ensilaged sugar beet leaves and tops.
$4\frac{3}{4}$ lb. cotton-seed meal.
2 lb. bran.
8 lb. oat straw.

*Farm horses.*

1 to 2 lb. dried sugar beet pulp.
15 lb. oats.
2 lb. beans when working hard.
9 lb. hay.

*Sheep.*

$\frac{1}{4}$ lb. dried sugar beet pulp.
$\frac{1}{4}$ lb. molasses.
$\frac{1}{4}$ lb. poppy-seed cake.
$\frac{1}{4}$ lb. kibbled barley.
5 lb. ensilaged leaves and tops.
$\frac{1}{4}$ lb. maize.
$\frac{1}{4}$ lb. rice meal.

Daily rations on a farm in Holland:

*Fattening bullocks.*

180 lb. wet or 18 lb. dry pulp, or 140 lb. mangolds, plus concentrated foods (one of dry pulp is taken as equivalent to 10 of wet pulp).

*Store cattle.*

50 lb wet or 5 lb. dry pulp, or 40 lb. mangolds, plus meals and hay or straw (8 lb. mangolds are taken as equivalent to 1 lb. of ordinary diffusion dry pulp or 10 lb. of wet pressed pulp).

*Cows in milk.*

50 lb. wet or 5 lb. dry pulp, or 40 lb. mangolds, 20 lb. ensilaged sugar beet leaves and tops, along with concentrated foods and hay.

The question as to the value of the residual sugar beet slices or pulp for feeding to stock in this country was from the first recognized as being of the utmost importance, and accordingly large quantities of this foodstuff were purchased by The National Sugar Beet Association in 1911, and distributed gratis to agricultural colleges and other public bodies for feeding trials with stock. One of the trials was carried out at the Norfolk Agricultural Station with fattening beasts. The results showed that ordinary sugar beet dry pulp gave satisfactory results when compared with mangolds and swedes. Other trials with cows showed that the milk production was equal, but that the resulting butter was firmer and had a better colour when made from the milk of pulp-fed cows than with that of cows fed on mangolds. All other foods were alike for both lots of animals

in each trial. The proportion of the dried sugar beet pulp to mangolds was 1 lb. of pulp to 8 lb. of mangolds.

There are several feeding trials now in progress on milking cows to test the value of the dried slices or pulp sold by the Kelham factory. The results up to the present time confirm those obtained some years back both as regards quantity and quality of milk.

The quantities of dry pulp fed in the foregoing rations refer to the residual pulp from the usual, or diffusion, method of manufacture adopted on the Continent. When the Steffen process is used, as at the Cantley factory in Norfolk, the slices or pulp have a much higher sugar content, as less sugar is extracted for crystallization.

The following analyses show the difference:

| | Wet Diffusion Pressed Pulp. | Dry Diffusion Pulp. | Dry Steffen Pulp. | Mangold. |
|---|---|---|---|---|
| | Percentage. | Percentage. | Percentage. | Percentage. |
| Carbohydrates .. .. | 9·9 | 58·5 | 67·9 | 9·2 |
| Sugar .. .. | 0·4 | 4 to 5 | 30 to 35 | 5 to 6 |
| Digestible albuminoids | 0·6 | 3·6 | 3·5 | 0·8 |
| Fat .. .. | 0·1 | 0·6 | 0·4 | — |
| Fibre .. .. | 3·0 | 17·6 | 11·8 | 0·9 |
| Ash .. .. | 0·7 | 4·0 | 4·2 | 0·8 |
| Water .. .. | 85·0 | 11·2 | 8·2 | 88 to 90 |

## Labour Involved in growing Sugar Beet.

Without a doubt labour will always be one of the difficulties in the way of establishing the culture of sugar beet in this country. Although it is true that the sugar beet crop requires more labour than mangolds acre for acre, there is not, or should not be, a great difference; in fact the cultivation of mangolds should be as thorough as that for sugar beet, and the labour expended on these crops practically the same up to the time of lifting.

The chief difference is in the cost of lifting and topping; and roughly speaking sugar beet will cost from three to four times as much as mangolds for this operation.

## Costs and Yields per Acre of Sugar Beet and Mangolds.[1]

The following figures are given as typical examples of careful returns, kept in some 130 farms in the counties in 1912, under the supervision

[1] It is to be remembered that costs fluctuate from year to year, thus the figures given must be regarded mainly as affording a *comparison* of the costs involved in growing two crops which are in many respects similar.

of the writer. The figures are exact costs, as far as it was possible to work them out, with the exception of the estimated cost of carting to factory or rail.

The mangold and beet crops were grown alongside each other in the same field in all cases.

FARM NEAR DYMOCK, GLOUCESTER (Soil, red sandy loam)

| | Sugar Beet. | | | Mangolds. | | |
|---|---|---|---|---|---|---|
| | £ | s. | d. | £ | s. | d. |
| Carting and spreading dung: 15 loads at 6*d*.; spreading, 1*s*. 6*d*. per acre .. .. .. .. .. | 0 | 9 | 0 | 0 | 9 | 0 |
| Autumn ploughing .. .. .. .. .. | 0 | 10 | 0 | 0 | 10 | 0 |
| Spring cultivations: | | | | | | |
| Five times over with 3-horse cultivator at 3*s*. per acre | 0 | 15 | 0 | 0 | 15 | 0 |
| Twice harrowing at 6*d*. per acre .. .. .. | 0 | 1 | 0 | 0 | 1 | 0 |
| Once rolling with 2-horse roll at 8*d*. per acre .. | 0 | 0 | 8 | 0 | 0 | 8 |
| Carting and spreading manures .. .. .. .. | 0 | 1 | 0 | 0 | 1 | 0 |
| Drilling with 5-row drill (18-in. drills), 22nd April .. | 0 | 0 | 9 | 0 | 0 | 9 |
| Seeds, 15 lb. (beet) at 6*d*.; 10 lb. (mangold) at 8*d*. per lb. | 0 | 7 | 6 | 0 | 6 | 8 |
| First hand-hoeing .. .. .. .. .. .. | 0 | 4 | 0 | 0 | 4 | 0 |
| Chopping out and singling .. .. .. .. | 0 | 10 | 0 | 0 | 10 | 0 |
| Second hand-hoeing .. .. .. .. .. | 0 | 6 | 0 | 0 | 6 | 0 |
| Third hand-hoeing (beet) .. .. .. .. .. | 0 | 4 | 0 | 0 | 0 | 0 |
| Horse-hoeings, twice with Dutch hoe, at 9*d*. per acre .. | 0 | 1 | 6 | 0 | 1 | 6 |
| Lifting (using lifting plough) .. .. .. .. | 1 | 2 | 0 | 0 | 8 | 0 |
| Carting, clamping, and earthing up for mangolds, say .. | 0 | 0 | 0 | 1 | 0 | 0 |
| Carting of mangolds from clamp to barn, topping, tailing, and slicing, say .. .. .. .. .. | 0 | 0 | 0 | 0 | 5 | 0 |
| Cost of artificials .. .. .. .. .. .. | 1 | 16 | 3 | 2 | 7 | 6 |
| Estimated cost of cartage and putting on rail (beet) .. | 2 | 0 | 0 | 0 | 0 | 0 |
| Total cost of production, excluding rent .. .. | 8 | 8 | 8 | 7 | 6 | 1 |
| Rent, 30*s*. per acre; rates 2*s*. 2*d*. in the pound per annum | 1 | 13 | 3 | 1 | 13 | 3 |
| | 10 | 1 | 11 | 8 | 19 | 4 |

| | Sugar Beet | Mangolds |
|---|---|---|
| Yield per acre (beets washed and topped, mangolds topped) .. .. .. .. .. .. | 13 tons | 24 tons |

**Grower's Remarks.**

"I am quite satisfied sugar beet can be successfully grown on this farm. The greatest difficulty in the cultivation of the crop on a large scale in this country would be the labour. This field has been continuously cropped with mangolds for several years, and treated with fifteen loads dung supplemented by artificial manures each year."

FARM NEAR IPSWICH, SUFFOLK (Soil, light sandy loam)

(*a*) Sugar Beet

| | £ | s | d. |
|---|---|---|---|
| Autumn ploughing: wheat stubble ploughed and drilled with rye for spring feed .. .. | 0 | 6 | 0 |
| Spring cultivations: bottom of furrow broken up in April by plough without mould board .. | 0 | 5 | 6 |
| Ploughing .. .. .. .. .. .. | 0 | 8 | 0 |
| Harrowing and rolling .. .. .. .. | 0 | 1 | 0 |
| Drilling, 1st May .. .. .. .. .. | 0 | 1 | 6 |
| Seed—15 lb. at 6*d*. .. .. .. .. .. | 0 | 7 | 6 |
| First hand-hoeing / Singling or setting out / Second hand-hoeing .. .. .. .. | 0 | 16 | 3 |
| Horse-hoeings, three times at 1*s*. 4*d*. .. .. | 0 | 4 | 0 |
| Lifting, topping, and putting roots into heaps (hand lifted by contract) .. .. .. | 1 | 5 | 0 |
| Cost of artificials and applying .. .. .. | 1 | 19 | 6 |
| Cost of cartage and putting on rail .. .. | 2 | 0 | 0 |
| Cost of production, excluding rent .. .. | 7 | 14 | 3 |
| Rent .. .. .. .. .. .. | 0 | 15 | 0 |
| | 8 | 9 | 3 |

Yield per acre, washed and topped, 11 tons.

(*b*) Mangolds

| | £ | s. | d. |
|---|---|---|---|
| Cleaning operations during autumn .. .. | 1 | 0 | 0 |
| Carting and spreading dung[1] .. .. .. | 0 | 6 | 0 |
| Spring cultivations: Ploughing and dressing land down .. .. .. .. .. .. | 1 | 10 | 0 |
| Drilling .. .. .. .. .. .. | 0 | 1 | 6 |
| Seed—10 lb. at 8*d*. .. .. .. .. .. | 0 | 6 | 8 |
| First hand-hoeing .. .. .. .. .. | 0 | 5 | 0 |
| Singling or setting out .. .. .. .. | 0 | 1 | 6 |
| Second hand-hoeing .. .. .. .. | 0 | 5 | 0 |
| Third hand-hoeing .. .. .. .. .. | 0 | 2 | 6 |
| Horse-hoeings .. .. .. .. .. | 0 | 4 | 0 |
| Lifting crop .. .. .. .. .. .. | 0 | 7 | 6 |
| Carting, clamping, and earthing up .. .. | 0 | 12 | 0 |
| Carting from clamp to barn, topping, tailing, and slicing, say .. .. .. .. .. | 0 | 5 | 0 |
| Cost of artificials and applying .. .. .. | 1 | 12 | 6 |
| | 6 | 19 | 2 |
| Rent .. .. .. .. .. .. | 0 | 15 | 0 |
| Total cost .. .. .. .. | 7 | 14 | 2 |

Yield per acre, topped but not washed, 18 tons

[1] 10 loads of dung charged at labour only.

**Grower's Remarks.**

"No farmyard manure was applied for sugar beet. The field was cropped with wheat in 1911, and in 1910 received 10 tons dung on clover ley for the wheat crop.

"The figures given are absolutely correct.

"The month of June was too hot and dry, particularly as very little rain fell in April and May, but in a normal season the crop should have done better."

The following is an estimate of the working cost per acre for the sugar beet crop on the Kelham estate in 1922.

| | £ | s. | d. |
|---|---|---|---|
| Rent .. .. .. .. .. .. .. | 1 | 10 | 0 |
| Rates .. .. .. .. .. .. | 0 | 7 | 6 |
| Cultivations up to drilling .. .. .. .. | 3 | 1 | 3 |
| Drilling, harrowing, rolling .. .. .. | 0 | 12 | 2 |
| Seed .. .. .. .. .. .. .. | 0 | 10 | 10 |
| Manures and lime .. .. .. .. .. | 4 | 0 | 3 |
| Labour on manures and lime .. .. .. | 0 | 8 | 1 |
| Setting out, side hoeing, horse-hoeing, and weeding | 2 | 8 | 10 |
| Harvesting .. .. .. .. .. .. | 2 | 7 | 7 |
| Filling carts and hauling to rail .. .. .. | 1 | 14 | 0 |
| Cost per working acre .. .. .. | 17 | 0 | 6 |

**Indirect Advantages of Sugar Beet Culture.**

Sugar beet culture will help to raise the standard of farming wherever beet is grown extensively for a factory.

Such undoubtedly has been the result in the great sugar beet areas abroad. Higher yields of other crops, a greater head of stock per acre, increased value of land, and the general prosperity of the whole countryside has followed in the wake of the sugar beet.

The reason is that sugar beet is the best cleaning fallow crop in existence. Humus is maintained in the land by applications of dung and the large quantities of root fibres that are left in the land after removal of the crop. The minerals that are removed by the crop are largely returned to the land by feeding the pulp and leaves, or ploughing the latter in, and by the return of the factory lime. The sugar which is retained by the factory is manufactured in the leaves from carbon dioxide (carbonic acid gas) from the air and water from the soil, and therefore does not in any way rob the soil. The deep rooting nature of sugar beet (the root system penetrates to a depth of several feet) helps to open up the subsoil, and, by disintegration and aeration, gradually brings a larger area into a condition suitable for plant life.

All European countries except our own cultivate large areas of land for sugar beet, running into millions of acres. The labour is usually anything but cheap, and the rent in the good beet areas averages from £2, 10*s.* to £5 per acre.

In Holland there are something like 130,000 ac. of sugar beet grown annually, against 50,000 ac. of mangolds. Free trade is in existence, and the farmers are not tied up or obliged to grow sugar beet when they renew their contracts. They have a great dairying industry, and therefore know full well the value of mangolds. Why is it that they grow more extensive areas of sugar beet than mangolds? There can only be one answer, and that is that it pays them better to grow sugar beet.

We consume in this country something like 90 lb. of sugar per head per annum, and the demand is increasing. Surely we ought to produce as much of this as possible at home.

In conclusion I would specially draw attention to the fact that the sugar industry would not only help the landlords and farmers, but it would help many trades, and would develop enormous railway traffic.

Also we might look for better cottages and a general revival of trade in country districts to supply the wants of workers.

# THE CABBAGE CROP

By J. C. BROWN

All the members of the cabbage family, *Brassica oleracea*, are descended from the wild species, which, in the form of a useless weed, is to be found on the sea cliffs of the south of England. All the cultivated members of the *Brassica* family are rather unstable in character, and at the present time new forms arise with extraordinary frequency.

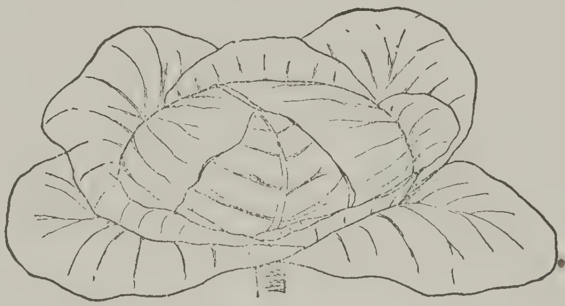
From the agricultural point of view the possibilities of this family have by no means been completely explored. The species admits of considerable improvement for agricultural use, especially as regards hardiness and keeping properties.

## Varieties Grown.

There are three types employed in field cultivation.

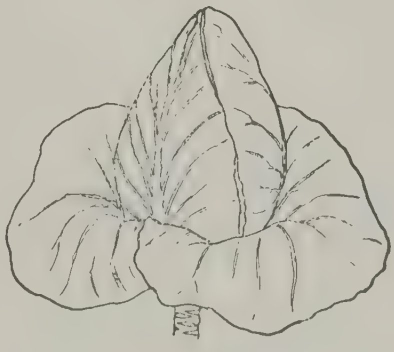
1. The drumhead or flat-headed type.
2. The oxheart or globe-headed type.
3. The conical-headed form.

Much more attention might profitably be given to improving the cabbage crop for field cultivation. The popular drumhead form is not



(1) Drumhead

(2) Oxheart



(3) Conical

Types of Cabbage

well suited for standing through the winter months; in this respect the conical shape is much superior, as it throws off the rain-water which penetrates the heart of the other forms, causing premature decay.

The hearts of the Winningstadt variety are hard enough to clamp in the manner practised in the case of roots. This peculiar hardness of the centre of this variety might be utilized in obtaining better agricultural types.

### Soil and Climate.

The cabbage family succeeds under a wide range of soil and climatic conditions, and is suited in different degrees to all conditions existing in the British Isles. The plants grow to the largest size in the cooler and better districts, but this crop is also one of the most reliable and satisfactory in the driest districts of the country. In view of the reliability of the crop it is a matter of some surprise that larger areas of it are not grown; no doubt the fact that it is more difficult to store during the winter months than roots militates against its more common cultivation.

The cabbage crop delights in soil fertility, and great yields are obtained on fertile loamy soils; on newly broken up land on the richest soils cabbages are often taken before a cereal in order to reduce the soil fertility to a level at which grain crops can be grown without becoming lodged. The cabbage crop can stand almost any excess of soil fertility, and is resistant to unhealthy soil conditions to a greater extent than any other arable crop. It can be grown with a fair degree of success on soils which, because of their condition, would not grow turnips or mangels, much less carrots or potatoes. Fairly heavy soils produce excellent crops provided that they are well drained. Light soils are less suitable, while wet, sour land is quite inimical to the growth of the crop.

### Cultivation.

Cabbages are usually taken after the cereal crop in the four-course system, and may be divided into three classes, viz. (*a*) early, (*b*) midseason, and (*c*) late.

**Early Cabbages.**—The seed is sown in carefully prepared seed-beds, made on land which is in good heart and free from perennial weeds. The beds must be well drained, as a wet condition of the soil during winter is fatal to young cabbage plants. The soil should be made firm to prevent the plants being thrown out of the ground by frost.

The seed is sown some time between the middle of July and the middle of August for producing plants for field cropping. Later sowing is liable to result in failure, except in the extreme south of England or in very sheltered situations. For field cultivation the early drumhead types are employed, but in the south these may tend to go to seed instead of

hearting. Transplanted in early May, the crop is ready for use in August.

On rich soils in sheltered situations the plants may be planted out from the seed-bed in the autumn; in this case shallow furrows should be made with the plough and the plants inserted in them so that they may benefit from the shelter thus rendered available.

The best spacing of the plants is obtained in drills 2 ft. apart with 1 ft. 6 in. to 2 ft. intervals between the plants in the drill.

**Midseason Cabbages.**—The seed should be sown in the seed-bed near the end of March; in the later districts the middle of April may be early enough. The plants grow away very rapidly and are ready to plant out about the middle of June; the early drumhead type gives a crop ready for feeding to stock about the middle of October, while Offerham will give fully developed heads by the middle of September; the yield of the latter, however, is smaller. Winningstadt, sown in the spring, is ready for use in November after the drumheads have been consumed. These varieties require ample space, and should be planted in rows 2 ft. 6 in. apart and with 2-ft. intervals between the plants in the rows. In the case of Winningstadt the intervals may be made smaller and a heavier crop obtained, as its conical shape allows of it being planted more closely on the ground. Planting and after-culture is carried out in the same manner as for early cabbage.

**Late Cabbages.**—These are either grown from seed in the nursery and the plants planted out or sown direct on the drills in the field and singled in the same manner as the root crops.

The seed may be sown in seed-beds in the previous autumn or even in the spring. Autumn-sown plants are very much more hardy than spring-sown ones, and in the case of the late drumhead and flat poll varieties, which are the best for the purpose—particularly the latter—they are not ready for use before winter, when they will stand hard frost. In the matter of resistance to frost the spring-sown plants score because they heart later; they do not, however, yield so heavily. For late winter and early spring use the Ormskirk Savoy should be planted.

Late cabbage in the field require plenty of space between the plants; the rows should be 30 to 36 in. apart, and the interval in the rows at least 2 ft. These varieties often produce single plants of great size where soil conditions are good. Cabbages which are allowed to stand through the winter are exposed to considerable risk of attack by wood pigeons, especially in frosty weather, and they are frequently the cause of great damage.

### The Cabbage Seed-bed.

For the autumn and winter feeding of dairy cows, a succession of cabbage can be obtained in field cultivation from early July until the end

of the year at a considerably smaller cost per food unit than is the case with the root crops.

Cabbage can be grown on good soils with a very small amount of cultivation. To secure the best results, it is necessary to sow the crop in seed-beds, preferably wherever possible in a sheltered corner of the field to be planted, as a considerable waste of time is involved in carrying the plants from a distant field during planting operations; however, if the soil is unsuitable for a seed-bed through being too wet or poor, a more suitable site must be sought.

The seed-bed should be manured with farmyard manure at the rate of 30 tons per acre. The land should be ploughed as deeply as is safe on that particular soil. The plough used should pulverize the furrow slice, leaving it in a crushed state; the surface should then be harrowed to a fine tilth which need not be deep. The cultivator or spring-tined harrow should not be used, as after these implements the earth becomes rapidly solid and unsuitable for the development of the rootlets of the plants.

The seed should be drilled in on the flat in drills 12 to 14 in. apart. The best machine available for this operation is the Plant pinion hand-drill, which can be regulated to sow at any rate required and perfectly uniformly. This drill is also provided with tines by means of which the seed-bed can be kept free from weeds with the minimum of labour. It may be remarked that any piece of land not free from the more serious perennial weeds is unsuitable as a seed-bed.

About 1 lb. of cabbage seed is required to provide plants to supply an acre of ground. It may not be out of place here to warn growers against sowing the seed too thickly, as is often practised by those who grow plants for sale. For field cultivation on the method advocated, large strong plants are required, as these will survive much more ill-treatment than smaller plants.

The ideal cabbage plant for field conditions is one with a really thick stem; such plants are almost indestructible; they can be planted in the driest weather and have a fair chance of survival. Plants of this kind can only be obtained by thin sowing. When the young plants have produced their second pair of broad leaves they should be dressed with sulphate of ammonia at the rate of 2 cwt. per acre. Overforcing must, however, be avoided as a too succulent growth is undesirable. The seed should be sown between the middle of July and the middle of August or during the first fortnight in April.

### Planting.

The commonest method employed in the growing of field cabbage is dibbling on raised drills made from 24 to 36 in. apart. This method is most suited to heavy or thin soils, but on deep loams it has no advantage over the much less costly method of planting on the flat directly into the

ploughing. When the last named method is followed it is necessary to use a plough with a concave mould board, the plants being laid out approximately the correct distance apart and drilled into the crest of the furrow slice.

The field cabbage has a strong root system, much more vigorous than that of turnips or mangels, and once the plant has taken root in the soil satisfactory growth follows.

Cabbage plants can be quite effectively ploughed in, thus saving the cost of hand labour. The plants are laid in every second or third furrow, and the furrow slice turned over on to them. If they are laid in carefully and the furrow skilfully turned, the plants will grow equally well with those planted in the usual way. A few may be knocked over by the horses, but generally the work proceeds quite smoothly. A wind, however, blowing hard across the furrows will make this method impossible. After ploughing in, it is sometimes an advantage to roll the newly planted ground to bring the furrow slices more closely together to grip the plants. The farmyard manure is ploughed in with the plants.

The machine used in America for the planting of the tobacco crop may be used with equal success for the planting of cabbages, and has the advantage of giving a dose of water with each plant. In dry weather this makes all the difference in giving the plant a start, and even when used in moderately wet weather the effect of the water is noticeable. Skilled operators are required to make a workmanlike job, and a good driver is needed with the horses. This machine will plant straight into the ploughing without any preparation, but the work is more easily carried out if a certain amount of harrowing is given before the machine is used.

In planting cabbages there are two points to be observed of outstanding importance. Firstly, the root must be inserted straight into the soil, and secondly, the soil must be brought firmly into contact with the whole length of the root; further, deep planting is desirable. Unskilful workers, when drilling, may leave a great part of the root out of touch with the soil and so give the plant a bad start.

In dry weather cabbage plants receive great benefit if, before they are planted, the roots are dipped in a thick liquid made of soil to which a quantity of sulphate of ammonia has been added. It is also an excellent practice to plant out cabbages from the seed-bed into nursery beds, allowing them to root before planting into permanent quarters in the field. When cabbage plants are withdrawn from the seed-bed, even if left on the surface of the ground in wet weather, they will develop a multitude of white roots which enable them to make effective use of the soil nutrients available. Plants from autumn-sown seed are much hardier and more resistant to adverse conditions than those raised in the spring.

In certain districts where the crop is required for sheep folding the seed is sown direct on raised drills or on the flat, and the plants singled

in the manner adopted for the root crop. When treated in this manner much smaller heads are formed with greater leafiness, resulting in greater ability to resist damage by frost. There is also less waste in folding than with a planted crop.

**Interculture.**

After planting, under ordinary weather conditions, the plants remain apparently dormant for about a month before growth above ground begins to take place. Cabbage plants, however, commence growth underground immediately after planting, the formation of a mass of white rootlets taking place within a few days of planting. Above ground the seed-bed leaves die off and nothing but the heart of the plant remains alive. At this stage the crop may be ruined in one night by rabbits and hares, which bite out the growing part from each plant, quite spoiling it from forming a heart even if it should survive.

By the time the plants have commenced growth, after transplanting, a number of weeds will have established themselves unless the ground is very clean. These must be destroyed by horse-hoeing, and sometimes hand-hoeing will also be needed. The best kind of horse-hoe for the purpose for use on average soils is one having heavy vertical tines turned slightly forward at the points, and so set that they penetrate deeply into the soil tilth in the bottom of the drills. The clearing of the weeds once is generally sufficient, as, following the initial rest of the plant after dibbling, the leaf formation is so rapid as to kill off the weeds underneath. It is, however, a great advantage to the crop if horse-hoed frequently up to the time when the leaves close the rows.

It may be noted that owing to the strong root system of the crop thorough preliminary cultivation of the soil is not needed. In the case of the root crops this is essential, but for the cabbage crop a properly turned furrow, with the weeds completely buried and the slice crushed only, is the best soil condition into which to insert cabbage plants. After planting, however, a dry free surface tilth between the rows is most effective in producing a rapid development of the crop. When well established this tilth becomes filled with a mass of white rootlets through which the crop draws its sustenance from the soil. The process can also be aided by running the double mould board plough along the bottom of the ridges to aid in deepening the free loose soil.

An objection many farmers have to the cabbage crop, and which applies more particularly to some of its open-headed relations, especially Thousandhead Kale, is the difficulty of dealing with the hard stems and extensive roots left after the removal of the crop. This difficulty, however, is easily overcome when ploughing by using a plough with a short mould board, a convex breast, and convex outer wing, and getting close up to the line of stems with the furrow previous to the one turning

the stumps under, then following this with a heavy furrow which buries the stumps completely and without difficulty.

Land which has carried a cabbage crop is dry after the removal of the plant, and when other land would be altogether too wet, can be ploughed and sown with wheat, if required, as soon as the crop is removed.

### Cabbage Seed.

Cabbage seed when sown should not be more than two years old, and preferably should be of the previous season's growth. 1 lb. of seed, sown on about 5 sq. poles of land, will produce sufficient plants for 1 ac. In growing cabbage seed there is great risk of hybridization from any plant of other varieties, resulting in nondescript forms being produced. Care must therefore be taken to see that there are no other forms of the *Brassica* family near enough the seed plot to allow of cross-fertilization taking place.

### Manuring.

The cabbage family are all gross feeders and capable of benefiting from the heaviest manurial dressings. To obtain maximum production, farmyard manure should be applied to land on which the cabbage crop is to be grown. Autumn application is preferable. 20 to 25 tons per acre should be given.

The crop responds to dressings of mineral manures and to applications of lime where there is a deficiency of this substance in the soil. Salt is also a useful aid in the growing of cabbage on certain soils; it has, however, the drawback of causing a stickiness of the soil, often harmful to the following crop.

The most potent manures for the cabbage are, however, the quick-acting nitrogenous manures, applied after planting, and the crop should never go without this treatment. As soon as the plants have recovered after planting, 1 cwt. of nitrate of soda or the equivalent of sulphate of ammonia should be given, a little of the manure being applied to each plant, and when growth is well established a further dressing of 1 cwt. to 2 cwt. should be applied to the crop, which will, if required, respond to still further applications of these manures, although the increase might not be so profitable.

Cabbage gives great yields when well treated, and responds to manuring more readily than the root crops.

The following is a useful average dressing:

| | |
|---|---|
| Dung.. .. .. .. | 20–25 tons |
| Superphosphate .. .. | 2–3 cwt. |
| Kainit .. .. .. | 2–4 ,, |
| Nitrate of soda .. .. | 3–4 ,, |

**Yield per Acre.**

This varies from 20 to 40 tons per acre on suitable soils when well cultivated, but on the poorer soils the crop may fall a good deal short of the lower figure. Under very favourable conditions great crops are obtained, but these have little interest to the average farmer. In all farm crops the exceptional yields are due to accident of soil or season, and cannot be reached where these favoured circumstances do not exist.

**Utilization.**

Cabbages are highly nutritious and are liked by all kinds of stock. They are largely grown for sheep folding in the autumn and winter in the south of England and are highly esteemed by flock owners. The value of the crop for fattening cattle or for milk production is scarcely appreciated to the full at the present time. The drawback to the use of the cabbage crop no doubt is that it cannot so easily be stored for winter use as roots, but it is nevertheless quite possible to store the heads of Winningstadt in clamps in the same manner as roots if the outside leaves be first removed —the more open-hearted types are not so satisfactory for this method of storing.

Apart from the possibilities of clamping cabbages, it is quite possible to arrange a succession of varieties to give fodder throughout the winter months. The daily carting from the field, which is so often objected to, has the advantage that the crop is only handled once, whereas the root crop is moved twice. A further advantage of the cabbage is that it can be fed to all kinds of stock without pulping.

In using the crop it is desirable to gather the heads as they ripen, so that each plant reaches its full weight before being cut and no heads are allowed to become decayed. The cabbage crop never ripens evenly, and cutting the crop from the side of the field is unsatisfactory because of the mixture of immature and over-ripe heads which are obtained.

Cabbages are sometimes said to taint the milk of cows, but in a well-ventilated and clean cowshed practically any desired weight of the crop can be used without risk of producing a taint if the heads are sound; it is the decayed leaves which form after the head is ripe that cause taints, and these should be removed and not fed to cows. Cabbages allowed to lie in heaps until they are slightly heated will also cause a taint. In cutting the crop care must be taken, when it is to be fed to cows, that the heads are severed immediately beneath the leaves, as the hard piece of stem immediately above the ground is liable to be swallowed without mastication and may cause choking. Cabbages can be fed to dairy cows in large quantities without causing scour; and they can safely be fed when frosted if the quantity is reduced and the ration of dry fodder increased. Up to as much as 120 lb. can be fed per day, and the flow of milk induced

thereby is greater than can be obtained by feeding roots. Cabbages and pea and oat hay are an excellent combination either for beef or milk production.

Cabbages can be fed to cattle through the hay rack when one is provided, and there is no need for any cutting of the heads. Cows readily take to eating cabbage, but there is so much difference between the varieties in leaf character that sometimes when a change is made from one variety to another time is required for certain animals to get accustomed to the change.

Altogether the cabbage crop is a most valuable one, and it should be even more widely grown than is the case at the present time.

# KOHL-RABI

By W. J. MALDEN, A.S.I.
AND
A. F. R. NISBET, M.A., B.Sc.(Agric.).

## Botanical.

Kohl-rabi (*Brassica oleracea*, var. *caulo-rapa*), as its botanical name signifies, is a form of cabbage with a thickened turnip-like stem. This stands quite out of the ground, though often close to it. The " bulb ", for which the plant is grown, is an epicotyledonary swelling, that is, it is a development of the stem above the first leaves. In this it differs from the swede and turnip, the roots of which are enlargements of the hypocotyl mainly. Like other cruciferous plants of this nature it sends down a vigorous taproot with a bunch of rootlets which enable it to withstand drought well. So marked is this property that it has been aptly termed " the bulb of dry summers ".

Kohl-rabi

The leaves grow out from the sides of the bulb, and the lower ones, as they drop off, leave the characteristic oval scars. In some varieties they are inclined to cluster at the top.

The leaves, thinner than in most cabbages, are smooth and glaucous, though in green-topped varieties there is a distinct light shade of green which readily distinguishes a field of kohl-rabi from either swedes or cabbage.

## Varieties.

The two varieties most generally grown are the Green Top and the Purple Top. From both of these, round and oval, late and early strains have been developed.

(*a*) *Green Tops.*—In these the leaves and bulbs are smooth greenish white. Those with the larger roots and more luxuriant foliage are suited to colder soils, while warmer soils favour those with smaller roots and fewer leaves.

(*b*) *Purple Tops.*—The leaves and bulbs of these are reddish purple or violet. Other varieties more delicate in nature are found on the Continent, but these are generally grown for table use.

The varieties may be otherwise classified into (1) early small-topped and (2) late hardy big-topped; or, again, according to shape.

Towards the end of the nineteenth century a specially big-topped hardy variety was in existence, but this has now gone out of cultivation.

## Suitable Soils.

Kohl-rabi thrives best on those soils which are intermediate between the light land where fairly good turnips may be grown and the heavier kinds where cabbages flourish. Thus on the medium to strong loams it gives the best returns, and in its early stages it responds best to a warm soil. The range of soils, however, on which the crop may be successfully grown is fairly wide, and once the plants have become established they can resist extremes of drought which would be highly injurious to other root crops. Thus we find kohl-rabi more commonly grown in the southerly parts of England than in the north and in Scotland. Again, from its comparative freedom from finger-and-toe, it is successfully grown in the Fens, where the large amount of organic matter and the scarcity of lime in the soil render swede growing precarious.

## Place in Rotation.

Kohl-rabi is mainly taken as a major crop, and occurs in a fixed rotation similarly to other main root crops. Or it may be grown as a catch crop in narrow rows and left unthinned. Alternatively it may be transplanted to land previously carrying an autumn-sown catch crop, in which case it has time to mature to a full crop.

## Cultivation.

The stubble land should be well manured and deeply ploughed in autumn or winter. Some start the spring preparation of the seed-bed by ploughing again, and there are still others who give three ploughings. The use of the spring-tined cultivator should, however, reduce this number and still give the necessary thorough tillage.

As the crop has been mostly grown in the warmer districts it is generally put in on the flat, but it is quite suitable for sowing on the ridge in the cooler and moister districts. Where drilling is practised the distance between rows may vary from 20 to 30 in.; while the distance between plants after singling will also vary—15 to 18 in. according to the variety. The globes require more space than the tankards.

The preparation of seed-beds for transplants requires special care. The area selected should be as sunny and sheltered as possible. Weeds must be avoided or removed lest they choke out the seedlings, and the ground must be mellow and reduced to the fineness of an onion tilth. It is not an advantage to make deep seed-beds; the object should be to produce shallow-rooted plants with fibrous rootlets near the surface, so that they may pull the more readily. If the tap-roots strike deeply, the rootlets are liable to be stripped off and the transplants will have difficulty in re-establishing themselves. To ensure shallow rooting a heavy dressing of superphosphate of 6 cwt. per acre should be given just before the final working prior to sowing the seed, which may be either broadcast or put in drills about 9 in. apart. Where broadcast, the seed should be raked in with a steel-toothed rake, or, where the area is too large for this, light seed harrows with sharp teeth should be used.

### Sowing and Transplanting.

Where the seed is to be drilled directly on the field, 4 or 5 lb. per acre are necessary, but 2 lb. in the seed-bed will give sufficient transplants for an acre. March and April are the best times for sowing where transplants are required; and for drilling in the field, in the warmer districts, the seed may be got in earlier than would be safe for swedes, since the rabi are more resistant to fungal diseases.

Early sowing is recommended so that the plants may reach the rough leaf before the Turnip Fly becomes active. In some seasons this is of first importance.

Besides drilling or transplanting on the whole field, a modification of these practices may be suggested. One row of rabi may be drilled in a four-row drill with mangels. This would give an abundance of plants with which to fill up the blanks in the mangel rows. An early variety of kohl-rabi will mature at the same time as the mangels, and may be removed with them, or left on the field and be fed off, when they will counteract any ill effects of the mangel leaves on the sheep.

As kohl-rabi is so little grown because transplanting is so often regarded as difficult and slow work, a few words may be given in respect to dibbling. Land to be planted should be cross-marked at the required distances by a marker-out, which may be a root drill with coulters set at the necessary width apart, or by a much wider implement with easy

steerage and light in draught, as is used in districts where much transplanting is done. The advantages of marking up and across a field are that as the rows cut at right angles the horse-hoes can be worked similarly; also a definite distance apart of the plants is assured when a plant is set at each crossing point. The dibble should be stout, not more than 8 or 9 in. in total length, and should have a sharp steel-shod point. As a rule a conical point is used, but in dry weather, on a loose tilth, a spud point is better, because if it strikes the ground somewhat diagonally the plant may be inserted under it with the moisture, and the loose dry soil will not crumble on to the roots, as it often does when a round dibble making a vertical hole is used. A great secret in planting is to insert the roots into moisture in dry weather and to firmly tread the soil about the plant. Most failures in transplanting in hot, dry weather come from allowing the dry crumbs of soil to fill the hole, and want of firm heeling in to compress moisture about the roots. Where the soil is very dry and loose it is often desirable to roll it.

Plants can be carried in a bunch in the left hand, or can be thrown broadcast at the required thickness about the ground. If carried in a bushel, seed lip, or basket a man soon acquires the habit of broadcasting sufficiently accurately for planters to find a plant as required without loss of time and without there being a surplus of plants. However, in dry weather scattered plants dry up quickly and are handicapped in re-establishing growth. Bunch planting is therefore better, especially as the crop can be kept from the sun except whilst being planted, and the roots can be dipped in water, or water with superphosphate and sulphate of ammonia or soot and water. Plants as drawn from the beds should be gathered into bunches with the roots in one direction, and the tap-roots cut off by a pair of shears or a knife. A plant placed in the ground with the tap-root upturned never prospers. Kohl-rabi plants are singled or transplanted, as a rule, to have rather more space than swedes and rather less than field cabbages.

The chief art in planting is to learn to squat and to make a quick thumb and finger pass of the plant as it is required, and to have it in a convenient position for insertion. The necessity of this is understood from the fact that a skilled planter ordinarily plants ten plants in a minute where the plants are placed 2 ft. apart. A really smart planter, with a well arranged bunch, can plant twenty plants in a minute, or a plant in three seconds, only a small portion of which is available for passing the plant.

To plant adroitly the planter must bend well at the knees, he must squat with a natural poise, when the back muscles will get no strain, and will be partly supported by the stomach against the thigh. The left knee particularly must be well bent. If this is done there is no danger of the dreaded backache; the other actions will come in the stride. The planter

places (quite unconsciously after doing it on a few plants) his right heel on the last-planted plant; his left foot goes forward so that the ball of the big toe is level with the mark in which he will put the next plant. During this time he passes the plant from the bunch into the required position, then he stabs the hole and, as he withdraws the dibble, inserts the plant before dry crumbs fall into it. He then either wedges earth up to the plants, or knocks it on with the point of the dibble and moves forward to repeat the operation of planting the next plant, bringing the right heel on to the plant just set, and firmly establishing it. The actions of planting are thus: (1) heel in the last plant with right heel; (2) left foot forward; (3) stab hole; (4) insert plant; (5) earth in, and then heel and repeat.

It is as easy as walking except getting the plant passed, which becomes a natural habit very quickly. In all this the back is horizontal at all times. If the back is straightened there must be loss of time; moreover, the power wasted each time in raising it from the horizontal is very great. The want of skill to accomplish this simple little operation, just described, learned in a few minutes, is the cause of so few cabbages and kohl-rabi being grown, and the loss to the country is a very serious one.

### Manuring.

The manurial requirements of the kohl-rabi are very similar to those of the cabbage, and so, much heavier dressings of nitrogenous manures can, with advantage, be applied than in the case of either swedes or turnips, and as for the other necessary manures—the phosphates and potash—they cannot reasonably be applied in excess. In practice the following dressing per acre generally meets the requirements:

| | |
|---|---|
| Farmyard manure .. .. .. .. | 15 tons |
| Superphosphate or basic slag .. .. | 4–5 cwt. |
| Kainit .. .. .. .. .. | 2–3 ,, |
| Nitrate of soda or sulphate of ammonia .. | 1–2½ , |

If the land shows the need for lime it may be given at the rate of from 10 cwt. to 2 tons per acre. Land in good heart which has been treated liberally with dung may require no other nitrogenous manure, but rabi being one of the gross feeders usually gives response to an extra 1 cwt. or so.

### Utilization.

Kohl-rabi is an attractive food to all animals on the farm. It is specially suitable for sheep, because there is no need to lift the roots, and there is no " shell " to hollow out as in the case of roots partly in the ground. The advantages are obvious in times of frost and snow.

The modern hardy big-topped variety has a hardiness against frost somewhat greater than the swede and is suitable for feeding after Christmas. The small-topped kohl-rabi is a relatively tender plant and better suited to autumn and pre-Christmas feeding, for it cannot be depended upon to withstand long hard frosts when it has matured. This variety is probably the most widely grown. As an autumn food it is safer than the swede, which until matured is liable to make sheep scour badly and does not develop its full feeding value. Kohl-rabi of these two varieties in succession gives reliable food from October to early February, after which the growth of the flowering stem deteriorates the bulb. The later variety is the more nutritive, and is not surpassed by any bulbing root in nutritive properties. In respect to this, shepherds with much experience both with swedes and kohl-rabi invariably urge that when cutting for trough feeding kohl-rabi is harder to cut, but that they are more than compensated by the small quantity required to satisfy the sheep and to keep the sheep improving at the same rate.

The dairyman has not appeared to appreciate the kohl-rabi in accordance with its merits, for not only is it very productive of milk, but it does not impart the unpleasant odour of the swede to milk. In this it demonstrates its cabbage properties. Many cowmen with a small area of arable land have a superfluity of dung, and as it is difficult to overdo the rabi crop, which has a great capacity for taking up manure and increasing the bulk of the crop without being injured, it is worth more attention from them.

Big plants have very strong roots which may be rather troublesome in working the land subsequently; but if care is taken to run the plough coulter close to the roots along the line of the drill it will generally be found that the next furrow will cover them so that they will not work out, but will decay in the subsequent crop.

The leaves make safe and good food and may be passed through the cutter when fresh. Care is needed in chopping off the bulbs not to leave too much hard root, for they make hard work for the man who is slicing them. A little practice soon provides the knack of preventing this. Sheep with good teeth find the small-topped variety as easy to gnaw as swedes, but the hardier variety, when grown large, are a trial to sheep with broken mouths.

## Storing.

Kohl-rabi store well and are easily cut off for this purpose; the cutting is done with a broad sharp rabi chopper or adze, the blow being made on the neck just under the bulb. They may be stored in fixed heaps at the customary chain apart for sheep which are folded, or they may be pitted in the ordinary manner for spring use.

A rapid method of storing is sometimes practised. Here a fairly deep

furrow is run up, the bulbs from two rows are placed in the hollow, and the returning plough covers those with earth which keeps them secure throughout the winter.

**Yield.**

Generally the yield is between 20 and 25 tons. It is found, however, in districts where rainfall is plentiful, that the tonnage is not up to that of the swede crop.

**Pests.**

Kohl-rabi is singularly free from the attacks of pests which ordinarily work havoc among cultivated cruciferous plants. The Turnip Fly is perhaps the worst enemy, but early sowing and the application of paraffin are fairly effective in avoiding destruction.

Finger-and-toe does little damage owing to the hard nature of the roots.

The Cabbage Root Grub may occasionally cut through the skin of the main root and kill or maim the plant. Fortunately this rarely occurs. When it does, a dressing of quickly acting nitrogenous manure will hasten on the growth.

Surface grubs, the Turnip Gall Maggot, and aphides do little damage as a rule.

There is the usual danger from wireworm, but this soon passes.

**Composition, Average** (Wood).

| | Percentage Total. | Percentage Digestible. |
|---|---|---|
| Protein .. .. | 2·0 | 0·7 |
| Fat .. .. .. | 0·1 | — |
| Carbohydrates .. | 8·2 | 7·4 |
| Fibre .. .. .. | 1·4 | 0·6 |
| Ash .. .. .. | 1·0 | — |
| Water .. .. .. | 87·3 | — |
| | 100·0 | |

It is found that kohl-rabi is richer in proteins (flesh-forming materials) and poorer in carbohydrates than swedes. The water content is also slightly less, which is an advantage where keeping properties are concerned. Not much difference is seen in the starch equivalent, though that for swedes is slightly higher, the figures being 7·5 and 6·7 (M'Connell after Wolff).

# RAPE

By W. J. MALDEN, A.S.I.

AND

A. F. R. NISBET, M.A., B.Sc. (Agric.)

## Botanical.

Rape belongs to the natural order Cruciferæ and to the genus *Brassica*, to which also swedes and turnips belong. Two species are generally grown, of which there are several varieties. These species are *Brassica campestris*, or Summer Rape, and *B. napus*, or Winter Rape. Seeds and seedlings of both these are very similar to those of other crucifers, and may easily be confused.

The plants differ from swedes and turnips in that they do not produce bulbs or "roots", but send up a green, rather fleshy stem with a mass of succulent foliage.

*B. campestris*, the larger of the two species, has smooth leaves, glaucous and fairly thick, and a well-defined tap root. In all features, except the lack of bulb development, this plant very closely resembles the swede. On the other hand *B. napus* is smaller, has roughish, sparsely haired leaves of a lighter green, and the root system is more fibrous and spreading.

Rape is a biennial, which entails that maturation does not occur till the second season. Seed production is very irregular, as the lower seeds ripen while the upper siliquas are still green.

## Varieties.

The chief commercial varieties are the Giant, the Essex Dwarf, and strains of these. The different uses of these will be noted later.

## Place in Rotation.

In a fixed rotation rape takes the place of roots after a corn crop, in which case the Giant variety is most commonly grown. However, rape being most accommodating in its ability to grow at almost all seasons,

and the short period of three months only being required for a heavy growth, enable it to be frequently taken as a catch crop. Thus it can be sown after early potatoes, or after corn which has been early harvested, either alone or with six-weeks turnips for autumn or early winter feed. Or again, it may be taken after an autumn-sown catch crop which has been fed off in spring or early summer.

Rape generally does best after early peas or winter beans, because these are harvested before the white straw crops; also because these pulse crops collect and leave behind more nitrogen. After a white crop the land is often depleted of available plant food.

**Cultivations.**

The cultivations for rape should be practically similar to those for swedes and turnips. There must be the same care in preparing a deep fine tilth as a seed-bed, and the manurings should be much in the same direction. Rape, however, as a plant producing much foliage, can stand without hurt a liberal dressing of nitrogenous manure, whether it be as farmyard manure or in concentrated form. If there is any rather special mistake in the growing of the crop, it is that when using it as a catch crop both manurings and cultivations are scantily given, with the result that poor, almost valueless crops are produced. The fact that useful crops are often grown with poor preparations in seasons when climatic conditions are altogether favourable has a tendency to cause carelessness.

The tillage for cruciferous catch crops, such as rape taken after corn, should be regulated so that the small quantity of moisture contained in the soil shall be conserved. Always, even in very dry years, there is some moisture available, but which is often lost. In the heat of July and August moisture is quickly dissipated, therefore no time should be lost behind the plough in working the land down to a tilth, and, as it were, closing it to the sun and wind. Moreover, it is far less expensive to reduce the soil then than when it has baked dry; further, a mellow tilth capable of retaining moisture is secured. As little as a lapse of half an hour will often make much difference in the success of the crop. Little land, unless very coarsely ploughed—for which there is no need—fails to come down well and contain enough moisture to germinate the seed. If the land is well worked throughout, the subsoil moisture will work upwards and ensure the establishment of the plant. Should even a small shower of rain come, the rape will quickly grow into safety.

The spring and summer treatment of land for roots always holds good; and the principle of holding moisture by not allowing it to be baked out from big clods around which sun and wind have full play accounts for the fact that, whilst the farmer who adopts it has often good crops, his less skilled neighbour has bad luck.

## Suitable Soils.

The range of soils on which rape may be successfully grown is wide, and this is further increased by its resistance to those diseases which are most destructive of swedes and turnips. Thus, though probably the greatest bulk of nutritive material may be taken off a rich loam, we find the crop flourishing on such widely differing soils as fen land, chalks, and fairly heavy clays. On the humus soils the Giant variety of *B. napus* is most favoured, while the ramifying rootlets of *B. campestris* give this variety the advantage on more argillaceous land.

In the chalk districts where catch cropping is largely practised, rape has an important place, as might be expected from the various times at which it can be sown. The high lime content here admits at times of rape succeeding rape.

## Manuring.

The manuring for this crop should be somewhat similar to the manuring of the turnip crop to which it is so closely allied, but as it is the foliage we wish to develop, nitrogenous manures can generally, with advantage, be used a little more liberally.

The crop responds well to dressings of farmyard manure, and 12 to 15 tons per acre may be ploughed in prior to the preparatory cultivation. There is less need for including farmyard manure in the scheme of manuring if the crop is ultimately to be consumed on the ground by sheep, but in cases where it is cut and carted to dairy cows or other classes of stock it is always advisable to include farmyard manure in the manurial dressing.

A particularly good response is given to applications of phosphates, and part of these should be given as superphosphate as that brings the crop away quickly. The other part may take the form of steamed bone flour, basic slag, ground mineral phosphate, &c., according to the nature of the soil.

Potash does not materially increase the yield unless where no farmyard manure is applied, but under such conditions it should never be omitted. Kainit or potash salts suit admirably.

Of the nitrogenous manures, sulphate of ammonia is fully the most suitable for application just prior to or at the time of sowing the rape, provided the soil contains a fair amount of lime. Nitrate of soda and nitrate of lime, on the other hand, are specially effective when given as top dressings.

The following represents suitable manurial dressings under ordinary conditions and can be relied on to produce large crops. When the rape is used as a " nurse " crop, however, and sown with grasses and clovers, the nitrogenous manuring should be restricted, otherwise the young seeds may be partially smothered.

**Manurial Dressings.**—(*a*) Without farmyard manure:

| | |
|---|---|
| Superphosphate .. .. .. .. .. | 3 cwt. |
| Steamed bone flour, or equivalent as basic slag, mineral phosphate, &c. .. .. .. | 2 „ |
| Potash salts, 30 per cent .. .. .. | $1\frac{1}{2}$ „ |
| Sulphate of ammonia .. .. .. .. | 1 „ |

These manures should be applied at the time of seeding. If the crop does not give promise of a full yield, a top dressing of $\frac{3}{4}$ to 1 cwt. nitrate of soda should be given from four to six weeks after seeding.

(*b*) With farmyard manure:

| | |
|---|---|
| Farmyard manure ploughed in .. .. .. | 15 tons. |
| Superphosphate .. .. .. .. .. | 2 cwt. |
| Steamed bone flour, or equivalent of other phosphatic manure .. .. .. .. .. | $1\frac{1}{2}$ „ |
| Sulphate of ammonia .. .. .. .. | $\frac{1}{2}$ „ |

In addition a top dressing of nitrate of soda should be given if required.

**Sowing and Utilization.**

From the nature of the crop, the time of sowing will vary with the purposes for which it is grown.

Either drilling or broadcasting may be practised. In the former case 4 to 5 lb. is a usual seeding, and 10 to 12 lb. in the latter. Where the drill is used a distance of 16 to 18 in. should be left between the rows, and a narrow thinning will result in more vigorous bushy plants. This method of seeding avoids to some extent a danger from drought, and facilitates the cleaning of the land.

Where rape is taken as a main crop it can be sown any time from the beginning of April. But when thus early, the land should have lain under the mellowing influence of winter weather so that a seed-bed is easily obtained. However, where a continuous supply of green food is desired in autumn and winter, successive breaks may be sown at any time after this up to August.

As a catch crop it is generally sown broadcast. This is quicker than drilling, and as the season is advanced weeds are less likely to hinder the growth, but should they spring up they have little chance of seeding and so fouling the land.

Taken after a catch crop rape is more favourably placed than if immediately after corn crops. The land is probably catch-cropped so that there is a bastard fallow to clean it; thus during the cleaning a suitable seed-bed is formed, enabling the crop to be sown in time to bring it to a full growth for autumn feeding.

The main purpose for which rape is grown in this country is to provide autumn and winter feed for sheep. Sown early, it comes to good growth

from August onwards and provides valuable food for lambs for sale. For fattening off shearlings of the long-wool breeds, sowing in June or July will provide keep at the required time.

A second feed may be taken by ewes in lamb, and again by the ewes when lambing from Christmas onwards. If the crop be fed off more than once in a season it is not such " sweet " keep at the second feeding as at the first, but by the third time, the winter frost has removed the injurious principles associated with " stale " keep. That it does go stale is an established fact, but the reason is not apparent. It may be that the fresh droppings of the sheep have some ill effect on the immediate growth.

On the rich fen lands rape grows with the greatest luxuriance and has great stock-carrying powers. It produces crops four or more feet high, and often big Lincoln sheep cannot be seen in the fold until they have been in for a few days and have bared the stems. Attractive as the leaves may be, it is found that the sheep thrive better when the stems are bared and the sheep eat them. Rape is valuable in sheep farming as an intermediary between grass and clover, and swedes; sheep not accustomed to cruciferous crops find the change to swedes too violent, especially in autumn before the swedes have matured. The maturity of swedes is not defined by the size, and until they have dropped their bottom leaves the food matter is in a somewhat crude form not easily digested; in fact, it appears that they contain some injurious substance, for the sheep are liable to scour badly and sometimes to have their digestion so upset that they die, when suddenly taken from grass to swedes. For generations it has been a practice over a large portion of the country to give a shilling or two more per head for lambs in autumn where they are known to have come off rape or cabbages, than for lambs similar in all other respects which have come from grass. However, in feeding off rape, care should be taken that sheep do not eat too ravenously when first turned in, or they may become " hoven " or " blown ", owing to the stomach being unable to commence digestion quickly enough to prevent fermentation which generates gases. As in the case of feeding off young clovers, sheep should not be turned in with empty stomachs or they feed too greedily, and the danger is increased if they are turned in when the crop is wet. It is safest to commence by feeding in small folds, and not to turn in the sheep for more than a short time. As with other green crops it is advantageous to give sheep some dry food to modify the over-succulence.

The growing of rape for seed is less common now than formerly. It is very simple to grow for seed, and has the advantage that a harvest may be obtained from a maiden crop or one that has been fed twice or even three times. The greatest yield is to be expected from a maiden crop, but where the feeding has not been too severe and the land is in good heart there will be little appreciable difference. Up to 35 bus. of seed per acre may be threshed out.

The harvesting of rape seed is practically similar to that of turnips and swedes. A harvest and threshing gang, where the seed is being taken from the field and threshed on the cloth (24 × 12 yd.), using two field iron rollers, is not less than twenty-six hands.

The seed is used as the source of colza oil, of which it contains 35 to 45 per cent. When expressed by machinery only 9 per cent remains, but by the use of solvents nearly all the oil is extracted.

The residue left by this process is known as "rape cake" or "rape meal". This has been used fairly extensively abroad as a cattle food, but is not favoured in this country owing to its pungent flavour, and the fact that it is commonly adulterated with mustard and charlock seed. The meal contains a high percentage of nitrogen, and is thus a useful manure. It has most popularity among hop growers.

### Analyses (Approximate).

| | Green Plant. Percentage. |
|---|---|
| Water | 85·9 |
| Oil | 0·8 |
| Proteins | 2·8 |
| Carbohydrates | 5·7 |
| Fibre | 3·5 |
| Ash | 1·3 |
| | 100·0 |

| | Feeding Cake. Percentage. |
|---|---|
| Water | 10 |
| Oil | 9·5 |
| Nitrogenous matter | 33·5 |
| Carbohydrates | 39 |
| Ash | 8 |
| | 100·0 |

| | Meal (manure). Percentage. |
|---|---|
| Water | 10·9 |
| Organic matter | 77·5 (= 5·2 N) |
| $P_2O_5$ | 2·3 |
| Lime | 1·3 |
| Alkalies | 3·6 (= 1·5 $K_2O$) |
| Sand | 4·4 |
| | 100·0 |

### Pests.

The rape crop is subject to many of those diseases and insect attacks which affect the swede and turnip. But the diseases of the bulb are missed except that finger-and-toe sometimes takes the young plants. Even here the ravages are not so severe, as the hard woody roots offer a strong resistance to the invading slime fungus.

In growing for seed the dangers are rather more serious, and the Turnip Seed Weevil and Turnip Blossom Beetle occasionally do considerable damage and are the seed-growers' worst enemies.

It should be noted that where rape is grown for seed to be used subsequently for cropping, care must be taken to avoid land where charlock prevails.

# KALE

By W. J. MALDEN, A.S.I.

AND

A. F. R. NISBET, M.A., B.Sc. (Agric.)

## Botanical Features.

The kales belong to the natural order Cruciferæ, and are descended from the wild cabbage (*Brassica oleracea*). Thus botanically they are designated *Brassica oleracea*, var. *acephala*. This indicates that they are of the cabbage tribe, but do not produce the characteristic "head" of that plant.

The seeds are similar to those of the other varieties of cabbage while the seedlings are also much alike, but it is when we consider the vegetative parts that we find the most marked differences.

The axillary and terminal buds of the kales in their first season grow out into leafy shoots, thus giving rise to an elongated stem bearing many green foliage leaves. Hence the kales as we now know them, though they have been produced by crossing varieties of cabbage, are more akin to their wild ancestor than to the hearting cabbages. Kale being normally a biennial plant does not produce seed till the second season. From the now woody stem the floral shoots arise bearing an abundance of yellow blossom, and later on are formed the rather hard siliquas containing the seeds.

## Varieties.

Since kale lend themselves to variation, and are cultivated both as a field and garden crop, we naturally find several varieties, the most important of which are the Thousandhead and Shepherd's Kale, grown almost exclusively on the open fields. The former has been grown as a farm crop for over a century, and it is commonly held that it arose as a selection from the Tree-cabbage or Jersey Kale, which is a giant among kale, rising several feet high, and is mainly grown for its sprouts. The great mass of

foliage makes the Thousandhead valuable, while the Shepherd's Kale has a leaf of much substance.

The Siberian Kale is found to be hardy and useful, and many foreign

Thousandhead Kale

varieties are descended from it. The varieties known as Borecoles and Scotch Kale are more generally cultivated for culinary purposes.

**Preparatory Cultivation.**

The kale crop should naturally come after a corn crop, the land thus receiving the benefit of the deep winter ploughing and a heavy dunging. It is, however, prevented from taking a definite place in a fixed rotation owing to the various times and different stages of growth at which it is consumed.

**Seeding.**

The seed may be broadcast, sown on ridges as for swedes and turnips, or sown on special beds and the young kale transplanted to the field. The fairly early sowing necessary only permits of a short spring cleaning

period, and so where the sowing is direct, clean land must be chosen. If, however, the method of transplanting be adopted, several additional weeks are available for preparatory cultivation; further, this allows in certain instances of a previous catch crop being fed off, but in such cases the cultivation prior to seeding must aim at conserving the moisture in the soil, for by June a young transplant is liable to die of drought. Thus the harrow and the roller should follow hard on the plough. This practice has the additional advantage of saving expense in seed and lessening the risk from the Turnip Fly, while against these we must set the cost of transplanting.

As the seeds to be sown are small and the young shoots not very strong the seeding must be shallow, and a fine seed-bed is necessary whether seeds are sown broadcast or by drill. In the production of a fine tilth the spring-tined cultivator is found most useful.

Thousandhead takes from ten to twelve months to come to its fullest bulk, that is, when the sprouts which give the plant its name, break in the spring. Thus it is desirable to sow in March or April so that the full yield may be got early in the following year and in time to permit of a cereal crop being taken after the kale.

It may here be noted that if the crop be grown for seed production it is most important that it be sown early in the season. If sowing is delayed the behaviour of the crop is erratic in the following year—the seeds of different plants ripening at different times and so causing a loss at harvesting. Crops for green forage, however, may be sown as late as July, and still give a fair yield early in the following year. Where the seed is being drilled in, from 3 to 5 lb. per acre is required according to the conditions. Where it is intended to draw plants from the drills for transplanting, the seeding should be slightly more liberal.

If the seed is sown on a special bed for transplanting, 2 lb. per pole is a fair seeding. But here, as in all cases, the quantity required to give a definite result depends largely on the condition of the seed-bed. Where the ground is lumpy, too cold, too wet, or too dry more seed is required; under favourable conditions less might suffice.

The space left between plants depends on what has to be the after-treatment. Thus where the crop has to stand through winter it is customary to place the plants 2 ft. apart on the square. This allows of a dense mass of fodder when sprouting is full. Where the kale is for winter feed only, the rows are often placed not more than 18 in. apart. When the crop is grown in 27-in. drills, as is sometimes the case, if intended for late consumption the plants should be left 18 in. apart, but if for early feed about 15 in. apart gives fully more produce.

Should sowing be delayed into summer, it is usual to drill in the whole of the land to be cropped and to single, if the crop is to be grown over the winter; or it may be left to grow out for autumn or winter feeding.

It is often sown broadcast for early use, the seeding being rather thick to smother summer weeds.

**Manuring.**

Like other crops of a similar nature, kale benefits by having the mineral manures (phosphates and potash) drilled in the seed row. This gives immediate help to the plant on germinating, increases the vigour of the shoot in forcing its way above ground, brings it quickly from the butterfly leaf (cotyledon) to the rough leaf stage, and so shortens the period of danger from the Turnip Fly.

The nitrogenous manures may be sown at the same time, but this is not so urgent, and they may be withheld until the plants are singled.

In ordinary circumstances Thousandhead Kale which has received no farmyard manure or other recent manuring requires 5 cwt. superphosphate, 2 cwt. kainit, and 1 to $1\frac{1}{2}$ cwt. sulphate of ammonia (or its nitrogenous equivalent of some other manure). These quantities will, of course, vary with circumstances; and from its robust nature and the fact that it is a " hungry feeder " the kale crop is unlikely ever to be over-manured. Indeed, the exceptional quantity of 3 cwt. sulphate of ammonia with the other manures (superphosphate and kainit) in proportion is not in excess where the cultivations are good and the plants not too crowded to destroy the lower foliage. But where the nitrogenous manure exceeds, say, $1\frac{1}{4}$ cwt., it is preferable to apply it in more than one application. Again, in dry times there is advantage in sowing it with or just before the seed, so that it may meet with the moisture necessary to make it active. If there is not sufficient of this moisture to dissolve it and carry it down to the roots, the plant loses its help when it needs it most. On weedy land it may be advisable to get it below the depth of the seed. The plants will soon find it, and it is well to tempt the roots downwards. Where near the surface, seedling weeds are liable to seize upon it, and in their vigour smother the kale and render the cleaning of the rows more difficult.

Where kale is transplanted the manure can be applied as soon as the plants are in; this may be done broadcast, though it is preferable to strain it alongside the rows or hand drop it near, but not on, the plants.

**Cultivations.**

The crop can be grown either on the ridge or on the flat—so far it has mostly been on the flat. Thousandhead is suitable to grow on a wide variety of soils, but like other cabbage crops prefers land of fairly strong staple. However, if a lighter soil be deeply worked and well manured, good crops can be grown. Excellent crops are possible on the strongest land, provided it is not waterlogged, and some of the very best have been

grown on really heavy land with a stiff clay subsoil only a few inches below.

The cultivations after the crop is in are very similar to those for swedes where drilling and singling is practised; where the kale has been transplanted the treatment resembles that of cabbages. It is impossible to give too much hand- and horse-hoeing until the ground is well covered and shaded from the sun. The maintenance of fine tilth greatly helps the young plants by encouraging root development and by the retention of moisture, apart from the benefit derived from keeping down the weeds. It is an advantage of transplanted crops set out on the square that the horse-hoe can be worked in two directions at right angles to each other so that practically all the ground receives attention.

After any cutting or feeding off, the land should be well worked to encourage the crop into new growth, and where the foliage is stripped from the stem and taken away additional manuring may be necessary each time. This, however, will be regulated by the quantity already applied and the condition of the land.

### Utilization.

Under changing conditions, especially of sheep husbandry on arable land, it is probable that, with the decline in the growth of the swede, Thousandhead will be more widely grown. As with rape, though more markedly so, kale is not merely a one-feed crop—it can be fed off several times. Moreover, on good land it can be kept productive for at least two years. It is, further, the only crop except rape, grown as a root crop, that can be folded at all seasons of the year, but rape loses much more of its foliage in the dead of winter than does kale. The spring-sown crop may be used as autumn feed, that is, before it is in the sprout condition; or it may be left to throw sprouts in the spring and be fed off then.

By varying the time of sowing, the crop may be available for use at practically any season, so its value to the dairyman as well as to the flock-master thus becomes apparent. The growth after the crop is taken in spring becomes available in summer and is a good stand-by in dry seasons; while the spring crop itself, producing as it does a mass of succulent food, is to hand before young grass or other growths appear.

The advantages offered by this crop have not been fully appreciated by dairymen, nor has the flockmaster even made the most of it. For the most part they have rested content with the autumn growth and neglected the magnificent bulk of green succulent food which this crop could offer in the early spring at the very time when something of the sort is very much required for heavy milking cows or for ewes nursing twin lambs.

### Diseases and Pests.

It is characteristic of kales that they are exceedingly hardy and are

seldom cut down by frost. This more particularly applies to the field-grown varieties. They are, too, like other cabbages, more resistant to finger-and-toe than are either swedes or turnips, and can be grown with safety on land which is too badly infected with the causal slime fungus (*Plasmodiophora brassicæ*) to allow of either of these crops. Nevertheless seed-beds should be selected from free land, as the disease is most liable to affect the plants in the seedling stage.

Though it does not commonly do much damage to kale, the grub of the Cabbage Root Fly may be destructive where kale is left down some time. This is more noticeable where cruciferous crops are taken frequently.

White rust (*Cystopus candidus*), which attacks cruciferous plants generally, occasionally shows on kale leaves, though as a rule the harm done is slight.

During a hard winter kale often suffers badly from depredations by rabbits, hares, and winged game. When there is snow on the ground and food is scarce the succulent green forage proves very attractive and great damage results.

# MARROW-STEM KALE

By W. J. MALDEN, A.S.I.

AND

A. F. R. NISBET, M.A., B.Sc. (Agric.)

## Botanical.

The Marrow-stem Kale is what is known as a "variety-hybrid". That is, it is the result of crossing two distinct varieties—the kohl-rabi and the Thousandhead Kale, each a variety of *Brassica oleracea*. The possibilities of this cross were first seen by Mr. John Garton, and thus the name "French kale", by which it is sometimes known, is rather misleading as to its origin.

It possesses many of the good qualities of both parents, having a thick fleshy stem from the kohl-rabi, and from the Thousandhead the habit of sending out numerous sprouts. These features do not come to full development at the same time.

## Varieties.

Marrow kale, as it is generally known among farmers, has been produced in two species, namely, the Green-stemmed and the Purple-stemmed. The former has attained the greater popularity by reason of its higher

Marrow-stem Kale

yielding powers, but the latter is credited with being more resistant to frost.

### Suitable Soils.

In general one might say that the best marrow kale soils are those in which the swede thrives best; but the range is wide. It does well on soils varying from the light chalk loams to heavy Wealden clays. Persistently wet, undrained soils are unfavourable, as they are to all root crops. Besides the variety of soils which are suitable, the possible range of country is extensive and includes the whole of the root-growing area in these islands.

### Sowing and Planting.

The same cultivations and care in preparing the seed-bed are necessary here as for other crops of this type (e.g. kale and kohl-rabi). Marrow kale is not a difficult crop to grow, and may be drilled in at the rate of 3 or 4 lb. seed per acre, or sown in beds and transplanted to the field. This latter plan allows, as in the case of Thousandhead Kale, an autumn-sown catch crop to be removed in good time before the marrow-stems take its place. Early sowing is necessary where the crop is for winter use. The middle of April, and even on to the end of June, is a suitable time, though in a favourable season earlier sowing is an advantage.

Where the seed is drilled in and the plants singled, the grower must decide for himself the distance apart of the rows and the space to be left between plants in the row. In determining this he must consider the object for which the crop is grown, the nature and condition of the land, and the period at which the crop will be required. On medium soils 2 ft. between rows, and from 1 ft. upwards between plants in the row, does quite well.

If the young marrow stems be transplanted from a seed-bed they are usually put in on the square, which facilitates cultivation. The distances apart vary. Since the crop can be eaten at practically any stage, the shorter the period of growth allowed the closer together will be the plants. Many grow it as closely as a plant to the square foot; but this may be increased to 2 ft. on the square, and even more where the land is in good heart and the crop is to be allowed to go right to the sprouting stage.

The plants may be ploughed in if they are very big, or if the men are unskilled in transplanting. But this entails more trouble with the after cultivation and cleaning, since the plants are not placed so regularly.

### Cultivations.

The principles applied to the cultivations of swedes and turnips hold good for marrow kale. Cleaning and singling are on similar lines, and transplanting is done as for kohl-rabi. It may be grown on the ridge

or on the flat, and harrowing is sometimes practised in place of singling. This is chiefly to reduce the labour cost, and the results are fairly satisfactory where no great size is demanded.

## Manuring.

The manurial requirements of the marrow-stem kale are very similar to those of the cabbage. The actual amounts given vary considerably, and as usual are determined by the condition of the land, whether dung is applied, and the bulk aimed at. Thus amounts per acre varying as follows may be applied:

| | |
|---|---|
| Superphosphate .. .. .. .. | 3–6 cwt. |
| Kainit .. .. .. .. .. .. | 3–5 „ |
| Sulphate of ammonia (or its equivalent) .. | 1–3 „ |

As for all root crops the lime content of the soil must be maintained, and to this end 10 cwt. of ground freshly burned lime might with advantage be given, though should finger-and-toe appear a much heavier dressing would be necessary.

## Utilization.

Marrow kale is readily eaten by all manner of farm stock from hens to horses. It is found very useful for dairy cattle, as the green part of their ration, and has the advantage that it does not impart a turnipy or similar disagreeable taste to the milk.

As a folding crop for sheep and lambs it is much relished, and pig-keepers have adopted it largely both for folding and feeding in yards. When used by sheep and pigs in this way the expense of cutting and slicing is avoided; moreover, the feed is kept above the ground and so clean, and when other roots are frozen in the ground the marrow kale is available.

## Pests.

The Turnip Fly is more severe on this crop than on swedes, and therefore a specially good seed-bed should be prepared to avoid its ravages. Early sowing affords some safety against this pest, though it does not give complete protection. The numbers in the first few generations may be few, but with favourable seasons they rapidly increase and may do considerable damage towards the end of April and during May. The practice of growing the plants in seed-beds lessens the risk from the fly, since it minimizes the area under the crop at the dangerous season.

Finger-and-toe is not so serious a menace to marrow kale as to turnips on account of the strong woody roots which it develops. Still, this slime fungus may attack it, and therefore should be guarded against.

Mildews and moulds do less damage to the marrow stem than to turnips.

The flowers of seeding plants are, however, liable to severe insect attacks. Rabbits and hares in some districts are very destructive. They are much attracted by the sweetness and richness of the marrow stem, and in some cases it is necessary to net in the field against these robbers, which destroy, by nibbling through the stems, as much as, or more than, they actually consume.

# CARROTS

By E. A. PORTER, B.Sc. (Agric.)

AND

A. F. R. NISBET, M.A., B.Sc. (Agric.)

## Botanical.

The carrot belongs to the natural order Umbelliferæ, and is directly descended from the wild carrot (*Daucus carota*), which may be found growing by the roadsides and in dry pastures. In the wild state the carrot is an annual and has a thin woody root, but with the exception of these points the parent plant and the cultivated varieties are similar.

The fruit is a schizocarp consisting of two dry spiny mericarps. These constitute the commercial seed. On germination two long narrow cotyledons and a distinct hypocotyl appear above ground, while a slender tap root penetrates downwards. As growth proceeds the root seems to contract and draws the hypocotyl partly into the earth. Later, thickening of the root and hypocotyl commences and the distinction between these two is lost. The lower part of the root, however, continues to probe deeply into the soil and remains fibrous and stringy.

The " root ", when cut across, shows two distinct layers—an outer band and an inner core of slightly different hues. It should be the object of growers to obtain as wide an outer layer as possible, as this is the more nutritious part.

In the second season a solid ridged stem rises to a height of 2 or 3 ft., bearing the inflorescence—a compound umbel. The outer branches of this gradually curve inwards, giving the umbel a hollow nest-like appearance.

## Varieties.

We find considerable variation in carrots, as to their size and shape, rapidity of growth, amount of root above ground, and also their feeding value. The choice of a particular variety will depend partly on the purpose for which the crop is grown and partly on the nature of the soil. Thus a shallow soil demands a short thick root, or one which grows well out; while the red carrots are most favoured for table use.

White Belgian is the heaviest yielder. Its roots are very thick, of moderate length, and stand 6 in. above ground. It is adapted for most

soils and is hardy, though its feeding qualities are not equal to many of the other kinds. Very similar to this is the Yellow Belgian—a lower yielder but of rather better quality.

Red Altringham is the heaviest cropper of the red varieties. The roots are long and thick, and therefore a deep soil is required. The quality is good.

Long Red Surrey has deep tapering roots, narrow in proportion to their length. This variety is of fair quality, though perhaps more suited to the garden than the field.

The Scarlet intermediate varieties are short and very thick, and are therefore well adapted for the shallower soils. They are of first-rate feeding quality, and for general cultivation the intermediates are the most useful.

### Soils.

The carrot is by its nature a plant which requires a deep light soil for its best development. Very shallow soils and those which are stiff to work are unsuitable, though these in many cases might be greatly modified by thorough cultivations. For example, on the shallower lands subsoiling might with advantage be practised. This is a costly operation, but the area under carrots is as a rule small.

The fine deep tilth possible on a sandy loam gives most satisfaction, for where there is little depth, and the subsoil is stony or harsh, the roots are inclined to "fork" or become "fanged", which greatly diminishes their value.

It is also essential that carrot land be free from stagnant water. The deep tap root by which the plant draws up its supplies requires, besides moisture, a free circulation of air for its proper functioning.

The area devoted to the cultivation of carrots is not very large, being not more than about 10,000 ac. in England, 500 ac. in Scotland, and 250 ac. in Wales. They are successfully grown in the Stourport and Kidderminster districts of Worcestershire and around Lenport, Salop, but Lincolnshire, Yorkshire (East Riding), Cambridgeshire, Nottingham, Bedfordshire, Surrey, and Hampshire grow larger areas.

### Place in Rotation.

The correct place for this root in the rotation is between two straw crops. Ploughing in the stubble of the preceding corn helps greatly in keeping the soil well open, while the winter weather mellows it. Further, the deep tillage and subsequent cultivations leave the land in a suitable condition for the succeeding crop.

### Preparatory Cultivation.

As many of the weeds as possible should be removed from the land in autumn, as if left till the spring they may smother out the young seed-

lings, which are rather delicate. Indeed such pests as spurrey may entirely obliterate the rows.

Dung in as short a state as possible should be applied to the stubble and ploughed in. This is necessary so that it may become completely incorporated with the soil and so offer no resistance to the roots, as long unrotted farmyard manure is sometimes found to cause forking.

Nothing further is needed till the early spring (March or April), when a few turns with the grubber or cultivator and the harrows should be sufficient to break up the old furrow slice and thoroughly mix the manure in the soil for the seed-bed. Then, unless growing on the flat is practised, the land is ridged up.

## Manuring.

As has been indicated, well-rotted dung may be applied, but it is found that a more desirably intimate mixture of soil and manure is obtained where the previous crops have been liberally treated and the land left in a high condition. Where, however, it is necessary to supply artificials the following dressing should meet the requirements:

| | |
|---|---|
| Superphosphate .. .. .. | 4–6 cwt. |
| Muriate of potash .. .. .. | 1–1½ ,, |
| Nitrate of soda .. .. .. | 1–2 ,, |

The nitrate of soda may be applied in two lots—the second as a top dressing. A good application of soot is often harrowed in before sowing, and is also used to top dress the young plants, both on account of its manurial value (the nitrogen content being about 3 per cent) and as a preventive against the Carrot Fly.

## Seeding and Thinning.

The seed is generally sown at the end of April or beginning of May, and may be either on the flat or on ridges. Where the climate is dry and the land clean, growing on the flat has some advantages, but ridging is the commoner practice. The best width of drill ranges from about 15 to 20 in.

An ordinary mangel drill may be used, but when the sowing is done with it the rows are generally found to be too wide apart, resulting in a smaller crop and a larger proportion of coarse roots. Thus, a drill similar to this, but with smaller rollers and more closely set, is found most useful.

Owing to their spiny coating the seeds cling together and render sowing difficult. This, however, may be overcome by mixing the seed with fine sand or sharps. Under the most favourable conditions, from 2½ to 3 lb. of seed " diluted " with 2 bus. of sand will suffice for an acre, but under less favourable conditions as much as 5 lb. may be required. The sand may be moistened and the mixture kept for about a week (with

repeated turnings) to allow germination to commence before sowing. This gives the seedlings a better chance against weeds.

Where a small quantity of seed is used the need for thinning is avoided. This is to the good, as it avoids largely the attacks from the fly.

It is sometimes desirable on foul land to use the horse-hoe before the young plants are visible as distinct rows, so to overcome the danger of uprooting these, some tail corn may be mixed with the seed before sowing. The more sturdy growth of the oats indicates the position of the carrots, which can then be avoided.

Thinning, when it must be done, takes place as a rule three or four weeks after sowing. A narrow-bladed hoe is used, and the plants left 4 to 6 in. apart. With a thick braird thinning is more difficult, and bunches or clumps may be left by the hoe and singled later by hand. When the thinning is completed, hoeing, to keep down weeds, is the only operation now required till harvesting.

### Harvesting.

Towards the end of October the roots are pulled by hand after being loosened by a fork where necessary. The fork used has two long stout teeth with a rest at the neck for the worker's foot. The tops are twisted off and the roots thrown into heaps of 10 to 15 cwt. and covered with the leaves. These heaps are left for several days, and either sold off at once or collected into a large " bury " or clamp, and covered with straw and earth as for potatoes. If sand is available it is useful to mix some among the roots when pitting.

### Yield.

The best growers often find that the crop weighs out to 20 tons per acre. This, however, is exceptional, but the average may be taken at from 10 to 15 tons. White Belgian will give a higher yield than this; but often the demand is only for the table varieties.

### Utilization.

Carrots make good feeding for fattening cattle, and when fed to dairy cows give a good quality of butter. They are specially useful in keeping horses in good condition, but must be fed in moderation. From 7 to 12 lb. per day is sufficient for a working horse. Heavier feeds than this have a tendency to cause diuresis.

They are not easily fed off to sheep, as they are too deeply embedded in the soil, nor are they to be recommended for trough feeding except perhaps for the final stages.

The most constant demand is for table use. Thus from the somewhat

mixed crops that are often grown, the best roots are selected and marketed and the remainder retained for stock feeding.

## Composition.

| | Percentage. |
|---|---|
| Protein .. .. .. .. .. | 1·2 |
| Oil .. .. .. .. .. .. | 0·2 |
| Soluble carbohydrates .. .. .. | 9·3 |
| Fibre .. .. .. .. .. | 1·4 |
| Ash .. .. .. .. .. | 0·9 |
| Water .. .. .. .. .. | 87·0 |
| | 100·0 |

The carrot is one of the most nutritious of cultivated roots, and if the compositions be considered it will be further seen how favourably it compares with others.

## Pests.

The carrot under field conditions is not subject to such wholesale destruction from insects as are some of the root crops. It is, however, liable on occasions to severe injury from the grub of the Carrot Fly (*Psila rosæ*), which burrows in the root, giving it in places a rusty appearance and often causing the leaves to wilt. The Carrot Louse (*Aphis dauci*) sometimes effectually destroys the crown of the plant. Many other insects harm the crop now and then, but fortunately, as a rule, the extent of the damage is limited.

# PARSNIPS

By E. A. PORTER, B.Sc.(Agric.)

## Botanical.

The parsnip (*Pastinaca sativa*) belongs like the carrot to the natural order Umbelliferæ. These two plants, possessing many features in common, both structural and cultural, constitute the only members of this order grown as root crops. The wild parent of the present cultivated varieties is found growing as an annual or biennial weed on waste ground and waysides of chalky districts; and except for the great development of fleshy root, which now makes the plants of value, there is little difference between it and its descendants.

Commercial seeds consist of the thin flat mericarps of the schizocarp fruits. These differ from the carrot seeds in being smooth, and thus they do not present the same difficulty in sowing.

Germination and subsequent development of bulb from hypocotyl and root proceed as in the case of the carrot. But here the leaflets are not deeply pinnatisect, so the full leaves appear coarser and not at all feathery.

The flowering stem, which grows up to a height of 2 to 3 ft. in the second season, is hollow and deeply furrowed. This bears the compound umbels of bright yellow flowers, and later, the dehiscent fruits.

## Varieties.

There are only a few distinct varieties of parsnip grown. Probably the most common is the Hollow Crown, so called on account of the depression round the neck. Useful members of this type are the Gresham and Improved Crown. The former is broad across the shoulder, rather short, easy to lift, and a good yielder; while the latter is also thick in the shoulder and has a pleasing whiteness of flesh.

In the case of the Large Cattle Parsnip the crown is convex, and the root is longer and more tapering than in those already mentioned. Given a sufficient depth of soil this variety is a heavy cropper.

The short, broad, Turnip-rooted Parsnip is generally found in gardens.

This takes after the Hollow Crown in that a distinct concavity is seen on the top.

## Suitable Soils.

There is a somewhat wider choice of soils for the successful growth of parsnips than there is for carrots. Though native to the lighter and rather chalky areas, they do well on stiffish land where carrots would fail. Indeed, if we exclude the extremes of light and heavy, pratically any soil is suitable provided there is sufficient depth and freedom from stones. If, however, there be little depth, and stones or other obstacles be present in any quantity, the roots will almost surely become forked and malformed, with consequent reduction in value.

A deep, well-drained, free-working loam gives most satisfaction. The tap root can sink unhindered in search of food materials, and the root has the chance to grow perfectly symmetrical.

## Place in Rotation.

The parsnip as a crop should be grown between two straw crops. This arrangement gives the long period necessary for the full maturity of these roots, and allows of the thorough cleaning of the land, so desirable before the following crop is sown.

## Preparatory Cultivation.

As soon as possible after the stubble is cleared, 10 to 15 tons per acre of rotted farmyard manure is applied and ploughed in with a deep furrow. Then in early spring (February), as soon as the weather permits, the land is brought to a fine tilth with the grubber or cultivator and the harrows.

## Manuring.

For parsnips, as for carrots, it is better that the land be in a high state of cultivation and left rich from previous crops, than that it should require direct applications of manure. However, if it is considered necessary to enrich the soil the following dressing will be found effective.

| | |
|---|---|
| Superphosphate .. .. .. | 4–6 cwt. |
| Muriate of potash .. .. .. | 1–1½ „ |
| Nitrate of soda .. .. .. | 1–2 „ |

## Seeding and Thinning.

Seeding usually takes place at the end of February or beginning of March as the germination is slow. The seeds are thin and flat and require some skill in sowing. Thus the plan of mixing them with fine sand (as for carrots) is sometimes adopted. Probably the best method is to use a brush drill and sow them in rows about 12 to 15 in. apart. Where this

is done 6 to 8 lb. of seed is sufficient. It should be noted that the seed must be fresh. The power of germination rapidly deteriorates, and old seed may sometimes become mixed with the new.

Occasionally the seed is broadcast by hand and later the plants cut into rows by means of a horse-hoe with three broad feet. This has the advantage of cheapness but is a very crude method.

When the plants are a suitable size they should be singled with a narrow hoe, leaving a space of 6 to 8 in. between them.

Except for an occasional hoeing to keep down weeds, no further attention is needed till harvesting.

### Harvesting.

The operations here are similar to those for the carrot crop, except that owing to the parsnip's greater resistance to frost the roots may be allowed to remain in the ground and lifted only as required for use.

### Yield.

The yield varies from 10 to 20 tons and is on the whole rather greater than that from the carrot crop.

### Utilization.

The chief demand is for table use, though in districts where they are grown it is customary to market only the best roots and feed the remainder to stock. For this purpose they are of considerable value, being the most nutritious of all the root crops grown.

They stand storage well, and may be pitted to provide winter and spring feeding for cattle or milk cows.

### Pests.

The parsnip, though liable to be attacked in the seedling stage by slugs and by a variety of insects at later periods, enjoys, on the whole, greater freedom from these pests than does the carrot. In particular the Carrot Fly (*Psila rosæ*) does little harm, though the Parsnip Leaf Miner (*Tephrites onopordinis*) often does considerable damage to the leaves by forming large blisters.

# COMPOSITION AND NUTRITIVE VALUE OF SUGAR BEET, KOHL-RABI, CABBAGE, KALE, RAPE, CARROTS, AND PARSNIPS.

By Professor T. B. WOOD, C.B.E., M.A., F.R.S.

As a class these crops are succulents. With the exception of the sugar beet, which contains as much as 24 per cent of dry matter and as little as 76 per cent of water, they contain from 12 to 15 per cent of dry matter and from 88 to 85 per cent of water. Of their dry matter carbohydrates form the major part, usually in the region of 60 per cent. The main carbohydrate constituents again are the sugars, usually a mixture of cane sugar, grape sugar, and fruit sugar. Again the sugar beet is an exception; approximately 80 per cent of its dry matter is sugar, and that nearly all cane sugar, which, however, splits into grape sugar and fruit sugar when the roots begin to sprout. Besides the sugars, the remaining part of the carbohydrates includes little or no starch, and a considerable proportion of pectins and other rather ill-defined compounds.

It is noteworthy that although these pectins are apparently not attacked by the ordinary digestive ferments, they are well digested by farm animals, probably through the agency of the intestinal bacteria. When decomposed by bacteria or by boiling with dilute acids they yield a mixture of sugars and some organic acid. Their nutritive value approximates therefore to that of the carbohydrates.

Succulent crops, such as those under discussion, are credited with a small content of fat, about half of which is digestible. Little is known as to the composition or food value of the fat. It forms, however, so small a proportion of the dry matter as to be almost negligible.

Protein, too, is not an abundant constituent of such crops. It usually amounts to only about 2 per cent of the crop in its natural condition, or something like 20 per cent of the dry matter. This figure, however,

refers to what is known as crude protein, i.e. nitrogen $\times$ 6·25, the assumption being that the whole of the nitrogen is present as protein. This is by no means true. Usually only from 30 to 60 per cent of the nitrogen is in the form of true protein, the remainder being present as amides or even as nitrates. Amides, of which asparagin and glutamin are the commonest, are usually considered to be half-way stages in the building up of proteins.

It will be seen from the above that these crops supply bulk, succulence, and abundance of readily digestible carbohydrates, and their high digestibility endows them with considerable value as productive fodders. In other words, they supply a considerable proportion of energy in a form which the animal can use for production of growth, fat, or milk. Their bulk, however, precludes their use in large quantities for horses or other working animals. Their real value, therefore, is for the production of growth, fat, or milk in the case of cattle, sheep, and pigs. When used in the fresh state, as is almost invariably the case, those of them which have been tested, notably cabbage and carrots, have been found to be good sources of vitamines, fat soluble A, water soluble B, and antiscorbutic. For this reason they are especially valuable as additions to the winter ration of young animals and milch cows.

The great productive value of succulent fodders is frequently overlooked by modern owners of live stock, who seem to be more or less obsessed by the great value of cakes and meals. On the basis of their dry matter content, succulent fodders, on the average, have a starch equivalent of 63 lb. per 100 lb. of dry matter, and the variations from this figure are not great. This suggests that their food value is practically proportional to their content of dry matter, at any rate when used as a constituent of a reasonably balanced ration. Very few investigations on this point have been carried out, but what there are, notably an investigation of the relative food value of different strains of mangolds, confirm the above conclusion.

When consumed by folding on the land, such fodders should be supplemented by hay or straw chaff, or long hay—in the case of sheep about 1 lb. per head per day—and by a sufficiency of some kind of cake or corn to raise the protein content of the ration to between 0·25 and 0·3 lb. of protein per head per day. In calculating this amount it may be assumed that sheep folded on a succulent crop will eat about 14 lb. per head per day. With good quality hay very little extra protein will be required.

In the case of pigs folded on succulent crops the supplement should be corn or meal, which nowadays is often fed dry with excellent results. The pig's digestive apparatus is not adapted to deal with dry fibrous foods, such as hay or straw. Exact rationing is, of course, impossible under such conditions. The more corn and meal supplied the less green stuff the pigs will consume and vice versa. A very small ration of dry corn or meal will serve to keep pigs thriving and in excellent condition if they

are folded on a succulent green crop which is not too old and tough. Such treatment gives good results with stores and breeding stock. For fattening it is usual to transfer the animals to sties and slop.

For cattle the method of rationing should be as follows: give coarse fodder, such as hay or straw, up to maintenance requirements, e.g. 14 lb. per day for a 9-cwt. animal. For fattening the animal will require a further 10 lb. of dry matter, of which about 7 lb. may be given in the form of succulent fodder. The remaining 3 lb. should be given as cake or meal or a mixture. The choice of this addition depends first on its power to make up the digestible protein in the ration to about $1\frac{1}{2}$ lb. per head per day, and secondly on the price.

The same method may be used to work out rations for milch cows, in which case, however, it should be borne in mind that the ration must supply 0·6 lb. of digestible protein and $2\frac{1}{4}$ lb. of starch equivalent per gallon of milk per day—these quantities being in addition to the ration required to maintain the cow in fair condition.

Details of the composition of each crop are given below.

## SUGAR BEET

The average chemical composition of sugar beet as grown primarily for sugar production is as follows:

| | Percentage Total. | Percentage Digestible. |
|---|---|---|
| Protein .. .. .. | 1·1 | 0·8 |
| Fat .. .. .. .. | 0·1 | — |
| Carbohydrates .. .. | 20·4 | 19·3 |
| Fibre .. .. .. | 1·1 | 0·4 |
| Ash .. .. .. .. | 0·7 | — |
| Total dry matter .. .. | 23·4 | |
| Water .. .. .. | 76·6 | |
| Total .. .. .. | 100·0 | |

Sugar beet was first grown as a source of sugar about one hundred years ago. Early analyses show that its composition was very similar to the composition of mangolds, except that it contained from 1 to 2 per cent more sugar. Although many attempts were made to raise its sugar content by selective breeding, no appreciable effect was produced until about 1870, by which date the polarimeter, discovered in 1867, had been applied to the rapid determination of the sugar content of mother roots for breeding. By 1875 the sugar content in selected strains of sugar beet had risen from 10 per cent to 14 per cent. No further considerable improvement is evident until about 1890, following the application of Vilmorin's method, ensuring self-fertilization of mother roots and selecting only for stock purposes those mother roots which gave a progeny containing a high

sugar content. The general adoption of these precautions soon produced another jump in sugar content from 14 per cent to 16 or 18 per cent, between which limits the average percentage of sugar still remains.

There are, however, many strains of sugar beet with lower sugar content for which it is impossible to give an average analysis, since their composition varies from the analysis given above for beet grown for sugar to the analysis of what is called on the Continent fodder beet, which do not differ materially in composition from mangolds. The author has observed an almost invariable connection between the shape of the neck and the sugar content. A beet with a thin neck is rich in sugar, and vice versa.

The carbohydrates of the sugar beet consist in the main of cane sugar, which accounts for, say, 17 per cent out of a total of 20 per cent. After Christmas the cane sugar begins to undergo inversion, and this change becomes very rapid when the roots begin to sprout. It does not, however, directly affect the food value, for invert sugar has the same nutritive value as cane sugar. When sprouting begins respiration becomes active, and a considerable proportion of the soluble carbohydrates is oxidized and lost.

The sugar beet, like the mangold, does not contain all its nitrogen in the form of protein. Out of a total of 1·1 per cent of nitrogenous compounds calculated as protein, 0·8 per cent is true protein and 0·3 per cent amides and nitrate.

As calculated from its chemical composition, the starch equivalent of sugar beet is 15 lb. per 100 lb. of beet, or about twice that of average mangolds. This applies, of course, to sugar beet of the strains grown for sugar. It is doubtful if this value would be realized in practice, nor is it advisable to grow high sugar yielding strains for fodder purposes on account of the expense of the seed and the trouble of lifting. In case a crop has been grown which cannot be sold to a factory, it can be used in place of mangolds, replacing 2 lb. of mangolds by 1 lb. of beet.

**Sugar Beet Leaves and Crowns** are said to possess a high nutritive value. Their average composition is:

| | Percentage. |
|---|---|
| Protein | 2·4 |
| Fat | 0·4 |
| Carbohydrates | 8·3 |
| Fibre | 3·0 |
| Ash | 5·4 |
| Water | 80·5 |
| | 100·0 |

**Sugar Beet Slices.**—This is the residue of the sliced beets from which the sugar has been extracted. It is usually sold by the factories to those farmers who have supplied the factory with beet. In the early days of sugar-making in England much misapprehension existed as to the

nature of this feeding stuff. Many farmers used it as a substitute for cake or corn with unsatisfactory results. Its average composition is shown below:

| | Percentage. |
|---|---|
| Protein | 8·1 |
| Fat | 0·6 |
| Carbohydrates | 58·5 |
| Fibre | 17·6 |
| Ash | 4·0 |
| Water | 11·2 |
| | 100·0 |

Its real use is as a substitute for roots, for which purpose it should be allowed to soak up all the water it will absorb overnight. Practical feeding trials have shown that 14 lb. of dried sugar beet slices can take the place of 1 cwt. of mangolds. This agrees with its starch equivalent, which is 51 lb. of starch per 100 lb. of dried slices, or about eight times greater than that of mangolds.

## KOHL-RABI

The average chemical composition is shown below:

| | Percentage Total. | Percentage Digestible. |
|---|---|---|
| Protein | 2·0 | 0·7 |
| Fat | 0·1 | — |
| Carbohydrates | 8·2 | 7·4 |
| Fibre | 1·4 | 0·6 |
| Ash | 1·0 | — |
| Water | 87·3 | — |
| | 100·0 | |

The kohl-rabi, as might be expected, is very similar in composition to the swede, but on the average slightly more nutritive, containing rather more dry matter and rather less water. Its composition, however, as is the case with all roots, is very variable. Broadly speaking good land, high manuring, irrigation with sewage, or any other treatment which tends to produce very large roots at the same time increases the water content and decreases the nutritive value. As is the case with other root crops, the predominant constituents are the carbohydrates, which consist of cane sugar, grape sugar, fruit sugar, and pectins. In this respect the kohl-rabi resembles the swede and the common turnip and differs from the mangold and sugar beet, which contain nearly all their carbohydrates in the form of cane sugar, at any rate until the roots begin to sprout in the spring.

Kohl-rabi are used for winter fattening of cattle and sheep, replacing swedes in certain districts whose soil and climate are unsuitable for swede growing. In these districts they have a great reputation as an occasional addition to the ration of horses. They are used for milk production, but like most crucifers they contain traces of sulphur compounds (mustard oils) which are liable to give an unpleasant flavour to milk and butter if used in excess or immediately before milking. In this respect, however, they are less liable to taint milk than either swedes or turnips.

## CABBAGES

From the point of view of their chemical composition, cabbages may be divided into two classes, viz. (1) drumhead varieties, which form a large flattened spherical heart which is so very close and dense that the inside leaves are almost completely blanched, (2) oxheart varieties, which form more or less conical heads in which the inside leaves are much less closely packed and still retain some green colour.

The average composition of these two classes is shown below.

| | Drumhead. | Oxheart. | Drumhead. | Oxheart. |
|---|---|---|---|---|
| | Percentage Total. | | Percentage Digestible. | |
| Protein .. .. | 1·5 | 2·5 | 1·1 | 1·8 |
| Fat .. .. | 0·4 | 0·7 | 0·2 | 0·4 |
| Carbohydrates .. | 5·9 | 8·1 | 4·6 | 6·5 |
| Fibre .. .. | 2·0 | 2·4 | 1·4 | 1·7 |
| Ash .. .. | 1·2 | 1·6 | — | — |
| Water .. .. | 89·0 | 84·7 | — | — |
| | 100·0 | 100·0 | | |

It will be noticed that the more open-leaved variety contains less water and more dry matter, and has in consequence a much higher nutritive value. Its starch equivalent per 100 lb. is 9·5 as compared with 6·6 in the case of the drumhead varieties.

Cabbages are most commonly grown for feeding dairy cows in the autumn and spring, for which purpose they are very successful, except that like other crucifers they are apt to taint the milk unless fed immediately after milking.

They are good food for sheep.

## KALE

Two varieties are commonly grown for fodder, Thousandhead, which has been in cultivation for a long time and has made its name, especially in the recent dry years, as one of the best drought-resisting fodder crops, and Marrow-stem, a much more recent introduction of which unfortunately

reliable analyses are not available. The composition of Thousandhead is given below:

| | Percentage Total. | Percentage Digestible. |
|---|---|---|
| Protein .. .. .. | 2·5 | 1·8 |
| Fat .. .. .. .. | 0·3 | 0·2 |
| Carbohydrates .. .. | 8·7 | 7·0 |
| Fibre .. .. .. .. | 1·7 | 1·2 |
| Ash .. .. .. .. | 1·6 | — |
| Water .. .. .. | 85·2 | — |
| | 100·0 | |

Thousandhead is much grown as winter fodder. It stands drought and frost well, and is usually folded, less frequently cut, and fed in buildings. It is often used for lambing ewes. It is less watery than roots or drumhead cabbage. Its starch equivalent per 100 lb. is 8·8.

Marrow-stem Kale differs from Thousandhead in being less branched, and in having a very thick fleshy stem. It is, like Thousandhead, a good drought resister and stands frost well. It is coming into use more and more, and is beginning to be used for folding pigs on the land. Although reliable analyses are not available, its composition is probably similar to that of Thousandhead.

## RAPE

Rape contains rather less water and rather more dry matter than do turnips or swedes. Its composition is given below:

| | Percentage Total. | Percentage Digestible. |
|---|---|---|
| Protein .. .. .. | 2·8 | 2·0 |
| Fat .. .. .. .. | 0·8 | 0·5 |
| Carbohydrates .. .. | 5·7 | 3·9 |
| Fibre .. .. .. .. | 3·5 | 1·9 |
| Ash .. .. .. .. | 1·3 | — |
| Water .. .. .. | 85·9 | — |
| | 100·0 | |

Its dry matter is, however, distinctly poorer in digestible carbohydrates and richer in fibre than that of the root-producing members of the order Cruciferæ. It is usually consumed in the green state and when quite young. No doubt it would become tough and fibrous if allowed to stand before being folded. On account of its rather high content of fibre its starch equivalent is somewhat lower than that of swedes, 6·9 as compared with 7·3.

Rape is usually consumed on the land by sheep or pigs folded on it

when it is young. It is an excellent crop for this purpose. Less frequently it is grazed by cattle, and less frequently still cut and fed to dairy cows. In the latter case it should be given immediately after milking, so that the sulphur compounds it contains may not taint the milk. American writers state that wet rape is apt to irritate the skins of pigs which are folded on it, and cases of this kind have occurred in England. The cause of the irritation is not known.

The seed of rape contains about 40 per cent of oil. Certain varieties of rape are grown on the Continent in order to obtain oil from the seed. The oil is obtained by pressing, and is known as colza oil. It is a non-drying oil of high viscosity. Formerly it was very largely used for burning. It is still used for that purpose to some extent, but its main use is to add body and viscosity to mineral oils used for lubrication.

## CARROTS

The average composition of the varieties of carrot grown for fodder is:

| | Percentage Total. | Percentage Digestible. |
|---|---|---|
| Protein .. .. .. | 1·2 | 0·8 |
| Fat .. .. .. .. | 0·2 | 0·1 |
| Carbohydrates .. .. | 9·3 | 8·9 |
| Fibre .. .. .. .. | 1·4 | 0·7 |
| Ash .. .. .. .. | 0·9 | — |
| Water .. .. .. | 87·0 | — |
| | 100·0 | |

The carbohydrates consist largely of sugars. Carrots contain a colouring matter known as carotin. This pigment is found in green plants in association with chlorophyll. The same pigment is found in milk, and gives the colour to butter. In summer when cows are at grass their milk and butter are distinctly yellow because they get a sufficient supply of carotin from the grass and other green food. On winter rations their milk and butter are often pale in colour because carotin is absent from roots, straw, cakes, and meals, and even from hay which has been bleached by rain or sun. Carrots are sometimes added to the winter ration of cows under these circumstances.

Carrots are of high feeding value compared with most succulent foods, their starch equivalent per 100 lb. being 8·8.

They are not grown widely for fodder. A common practice is to grow them for sale for human food, in which case they are used for fodder if they are not found to be saleable at a remunerative price. They are usually given to cows or to horses.

## PARSNIPS

The food value of parsnips is somewhat higher than that of carrots, as shown below:

| | Percentage. Total. | Percentage. Digestible. |
|---|---|---|
| Protein | 1·3 | 1·0 |
| Fat | 0·3 | 0·1 |
| Carbohydrates | 11·3 | 10·9 |
| Fibre | 1·2 | 0·7 |
| Ash | 0·9 | — |
| Water | 85·0 | — |
| | 100·0 | |

Parsnips contain less water and more dry matter than any other root crop except the sugar beet. Their most abundant constituent is carbohydrate, which is largely in the form of sugar. Their starch equivalent is high, 10·6 per 100 lb. They are grown for human food, and only used as fodder if not saleable at a remunerative price.

# COST OF PRODUCTION OF POTATOES, TURNIPS, ETC.

BY JAMES WYLLIE, B.SC., N.D.A.(HONS.)

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This article is a continuation of the article on the COST OF PRODUCTION OF GRAIN CROPS in Vol. I, p. 303, and should be read in conjunction with it.

It should be remembered that the cost of production of any farm product was defined to include the following items, viz.: (1) labour—man and horse, (2) seed, (3) manures and cleaning costs, (4) rent and rates, (5) general expenses, (6) interest on capital, and (7) management; and it was stated that consideration of the method of determining the charge to be made against each crop for manures and cleaning costs could be most appropriately taken up under root crops. This will now be done.

Of the various factors in production-cost number (3) above is not only one of the most important but also the most difficult to determine accurately—although accuracy in the mathematical sense is impossible. In fact, unless some satisfactory method of dealing with the apportionment of manurial and cleaning costs can be devised, it is futile to attempt the preparation of individual crop, as opposed to rotation, costs; and the method adopted must be both sound in principle and widely practicable.

### Manures (including lime and farmyard and liquid manure).

Manures may be either purchased (chiefly artificials and lime) or home-made (farmyard and liquid manure). The cost of the former is easily found; the determination of the price to be charged for the latter is, however, a problem in itself and one of fundamental importance, since this form of manure is one of the connecting links between live stock and crops in the farm economy, and the price attached to it has a direct bearing upon the relative profits from live stock and from crops. Else-

where[1] the writer has discussed this problem at some length and arrived at the conclusion that farmyard manure should be charged to crops (and credited to live stock) at the prices current in the different districts in valuations between outgoing and incoming tenants. Recent experience has confirmed the validity of this view and has shown the impracticable nature of other proposals which have been made. In districts where the farmyard manure is handed over free of charge (i.e. except for any labour costs which have been incurred in handling it), the price to be charged can be readily fixed on the basis of the charges made in adjacent districts. In short, farmyard manure is charged at what practical men consider to be its "farm value".

The first step, then, is to charge each crop with the cost of all purchased manures, and with the farm value of all dung, directly applied to it. The second problem that arises is to determine what credit, if any, must be given to each crop for the manures not used up or "exhausted" during its year of growth, and how this credit is to be disposed of. Numerous "scales of exhaustion" have been drawn up, but nearly all of these overlook the fact that one of the chief desiderata is the quantity of manure *per acre* originally applied, and they attempt to apportion, on a purely percentage basis, the benefits derived by the several crops. Other things equal, the percentage of farmyard manure, for example, left unexhausted after a potato crop will be much greater for a 20-ton dressing per acre than for only 10 tons. However, this is not the place to discuss the whole question of the distribution of manurial benefits; all that can be said is that the cost accountant, in conjunction with the farmer, must decide as accurately as possible, having regard to all the circumstances of each case, how much credit is to be given to each crop for manures applied but not exhausted during its year of growth.

Next, how is this credit to be disposed of, to what crops is it to be charged, and on what basis is the apportionment to be made? The view commonly held is that each crop and each field must be taken separately, and the unexhausted portion of each application of manure carried forward year by year until completely exhausted. Apart from the large amount of somewhat complicated clerical work involved, all of which is based upon what has been aptly called "educated guessing" and in which errors are liable to accumulate, the principle of this method is open to question.

Take a simple example. It is (or was) a usual practice in Wigtownshire and elsewhere to apply from 8 to 10 cwt. per acre of bone meal to the turnip crop, not so much for its effects upon that crop and the succeeding corn crop, as to lay a foundation for three or four years' grass. In 1918 bone meal was costing up to £20 per ton, and the result of following out the above method would be that the cost of grazing in 1923 and 1924

[1] *Scottish Journal of Agriculture*, January, 1918.

would include part of the cost of this dressing at £20 per ton—at a time when bone meal may be costing no more than £8 per ton and when milk may be selling at a fraction of the 1918 price. More generally, it may be said that this method tends to maintain costs on a falling market and depresses them on a rising market—a result of very doubtful practical utility.

As a matter of fact, the farmer applied the bone meal in 1918 at £20 per ton in the face of the high prices then prevailing for milk, and realized that unless he was repaid for it then he had small chance of being repaid in 1923 or 1924.

The alternative method which the writer proposes, and which has been adopted in the costing investigations from which the data given here and in the previous article have been taken, is to take as a basis "the cost of replacement of the asset worn out or exhausted".

Consider the above example. It is the object of the farmer to maintain his grazing land in a suitable state of fertility from year to year. Each year's grazing exhausts the land to a certain extent of phosphates, potash, lime, &c., and in order to maintain its condition he applies each year, *inter alia*, a dressing of bone meal. That the bone meal is applied not directly to the grass fields but indirectly through the turnip crop is immaterial—the cost of replacing the lost fertility of the grass fields is that proportion of the bone meal dressing which ultimately benefits the grazing. In other words, the cost of grazing in 1918 would include part of the cost of the bone meal applied in 1918 (being the cost of replacement of the worn-out asset), the costs are high when the prices of the products are also high, the future is in no way mortgaged for the present, and the farmer is put in a better position to judge whether the policy of applying bone meal at £20 per ton was a sound one or not.

Exactly the same reasoning applies, of course, in times of low prices for manures, &c., and for farm produce: low costs are put against low prices for the produce.

It follows, then, that under this method the whole cost of manures applied in any year must be charged against the crops grown in that year, and the residues which have been credited to those crops to which the manures have been directly applied, must be apportioned as accurately as possible, having regard to the circumstances of each case. In this it would be futile to lay down even the most general rules. There is nothing at all revolutionary in the proposal to treat manurial costs in this way, in fact, it is the only logical method of dealing with them.

It will no doubt be asked, how does this procedure affect the unexhausted improvements account, in so far as that account is made up of manurial residues? When the first balance sheet is made up it should contain, as an asset, the estimated value to an incoming tenant of the manurial residues. At the end of the first year it will be necessary to

decide whether this amount is to be altered or not. In normal times, and where the farm is being worked on a well-established system, it is likely that no change would be necessary, i.e. the asset would be maintained at its original value by means of replacements; but, if thought necessary, part of the credits for manurial residues, made to the crops which directly received the manures, may be carried to the unexhausted improvements account, and only the remainder apportioned over the rotation, that is, part of the cost of manures may be capitalized and carried forward as an asset. In later years, the process may be reversed, and the stored up fertility represented by the manurial residues item in the unexhausted improvements account may be partly withdrawn and spread over the rotation.

Two further points remain to be noticed, viz.: (1) in apportioning manurial costs, temporary and permanent pasture must always be kept separate, since the former benefits and the latter does not benefit from the manures applied throughout the rotation; (2) the value of the manurial residues from foods consumed upon the land should be calculated and apportioned along with the residues from manures.

Finally, it will be understood that special cases will not be amenable to treatment on the above lines, but it is fairly certain that cost investigations in farming will have to be confined for many years to come to what may be called normal or typical cases.

### Cleaning Costs.

It is generally recognized that one advantage of growing root crops, especially potatoes, turnips, mangels, &c., is that they enable the land to be periodically cleaned, and hence it is urged that part of the cost of the tillages done for these crops should be charged against the other crops in the rotation which benefit by the cleaning. This gives rise to the terms "cleaning crops" and "cleaning costs". But it must also be recognized that even on perfectly clean land a corn crop grown after a root crop often requires less work than one grown after lea. If this additional factor be included in the reckoning, then "the cost of beneficial cultivations" would be a more suitable term than "cleaning costs".

In the first place, it is necessary to indicate exactly what is to be included under cleaning costs. Does it include the cost of cutting thistles in grass fields, pulling thistles amongst corn crops, spraying runch or charlock, and numerous other operations which may or may not be of immediate benefit, but which are necessary or advisable in order to maintain the land in a proper state of cleanness? A few thistles in a grass field do not appreciably affect the grazing value, but if allowed to multiply they will not only reduce the value of the grazing but also come to be a serious nuisance amongst corn, hay, and root crops. On the other hand, the spraying of charlock in a field of oats may increase the yield of grain

by from 10 to 30 per cent and at the same time minimize the work necessary for succeeding green crops. It will be noticed also that such weeds as charlock, runch, spurrey, &c., and to a less extent couch grass, onion couch, &c., are only troublesome and harmful when the land is under either corn or green crops.

In fact, the difference between the thorough cultivation and cleaning of the land in preparation for a root crop and the cutting of thistles in a grass field is only one of degree. Logically, the costs of all cleaning operations should be treated in the same way, but as a working proposition it is usual to charge the whole cost of such minor operations as have been mentioned above against the crops upon which the work has been expended. Further experience will probably show that the logical method is also the soundest and most practicable.

In this article, therefore, the term cleaning costs is used in a somewhat conventional sense, that is, in relation only to root crops.

It is commonly stated that the turnip crop is grown chiefly in lieu of a bare fallow, that the main object is to get the land thoroughly cleaned, and that the value of the crop *per se* is a secondary consideration. If this were so, it would follow that the turnip crop would be charged only with the cost of such operations as would not be required for a bare fallow (such as sowing seed, singling, shawing, &c.), and that the other tillage costs would be chargeable over the other crops in the rotation.

On the other hand, so far as dairying, stock rearing, and feeding farms are concerned the turnip crop is very often one of the most essential crops, as a crop, in the rotation—apart altogether from its function as a cleaning crop. On corn and sheep farms also, in the south of England and elsewhere, the profits from sheep depend very much upon the success of the root crop, which, so far as corn crops are affected, is grown to enable the land to be economically manured and consolidated, rather than to be cleaned. A bare fallow would not take the place of roots upon such farms, as it would involve giving up sheep and increase immeasurably the difficulty of keeping the land in good condition for corn growing. "No roots, no mutton" is a common enough saying in these parts, and another is "no sheep, no corn".

For these and other reasons which might be given one is forced to the conclusion that under modern conditions the turnip crop must be put in the same category as potatoes and mangels, that it is grown chiefly for its value as a winter food for cattle and sheep, and that its function as a cleaning crop is more or less incidental and of secondary importance. In other words, the turnip is grown (*a*) as a food, (*b*) to enable the land to be economically manured, and (*c*) to enable the land to be thoroughly cleaned. Under present conditions and in the majority of cases the third object is the least important.

On purely cropping farms, that is, where the income is derived almost entirely from the sale of corn, hay, and other crops, the turnip crop may be of comparatively little importance, and on these it may quite properly be considered as essentially a cleaning crop. Taking the country as a whole, however, such farms form a comparatively small class.

It is therefore proposed that, as a general rule, the turnip crop should be put on the same basis as potatoes, so far as cleaning costs are concerned, and the questions at once arise: how is the credit for cleaning costs to be arrived at and how is it to be disposed of ?

Here again no useful purpose can be served by laying down even general rules, e.g. that a certain percentage of the total cost of the tillages (apart from those specifically required on the respective root crops—planting or sowing seed, singling, harvesting, &c.) should be taken as a credit. Each case must be considered on its merits. With clean, friable soil practically all the tillage may be chargeable against the root crop, whereas as much as 60 per cent may be charged against other crops in the rotation in cases where the land is very foul and requires special cleaning operations.

Whatever credit is made for cleaning costs, i.e. in the accounts for root crops, must be apportioned over corn, hay, and temporary pasture upon an acreage basis unless and until a more accurate method can be discovered. It is well to notice that cleaning costs are treated in the same way as ordinary manurial costs, i.e. in the normal case they are written off against the current year's rotation of crops, and only under abnormal circumstances will any part of them be carried forward to future years. Similar reasoning applies here as in the case of manures.

One other question arises in this connection. Quite apart from cleaning operations, it is well known that one crop prepares the way for another, e.g. by stirring up the soil and enabling a good seed-bed to be obtained (barley after roots, seeds with a corn crop, &c.), or by enriching the soil in nitrogenous compounds and organic matter (wheat after beans, oats after wild white clover pasture, &c.), and so on. The farmer does not fix his cropping system blindly, but upon such a basis as will enable the maximum benefits to be obtained from the arrangement—benefits which may be in a sense incidental but which are nevertheless part of the general scheme of things. It is impossible, however, to translate such benefits into money values (although the effect of growing wild white clover in pasture might be estimated as equal to, say, a dressing of 1 cwt. per acre of sulphate of ammonia), and they are mentioned here merely as a reminder that individual crop costs must always be interpreted having regard to the various factors which are not reflected in them.

A comparison of the costs of different corn crops is much more valid than a comparison of the costs of the oat crop and the turnip crop. In the former case, errors (if any) will be present in something like the same

proportion in all the costs, whereas in the latter all the factors which are involved in deciding upon a cropping system are not included in the comparison.

Unless such considerations are kept in mind in the interpretation of individual crop costings, the conclusions formed are likely to be erroneous, misleading, and positively harmful. In fact, where costing results over a series of years show that a certain crop is being grown at a loss, the first question may very well be: in what way must this result be qualified because of the inherent defects in the costing system?—not, should a change be made in the system of cropping?

The only other question of principle which need be referred to here is the treatment of the "brock" portion of the potato crop—including potatoes under seed-size (chats), diseased, overlarge and misshapen tubers, &c. This crop is grown essentially either for saleable ware or seed or partly for ware and partly for seed, and the brock is best regarded as a by-product and credited at its average consuming value on the farm. The final data for potatoes will therefore be (1) cost per acre of ware and seed, and (2) cost per ton of ware and seed. In some cases turnip shaws will fall to be treated on the same lines.

## Costs of Potato Crop.

No complete data for early potatoes are available, but the table[1] on p. 219 summarizes the costs of production (including marketing) of main-crop (with some second early) potatoes in 1920 on twelve farms scattered throughout Scotland—four in the west and south-west and eight in the east and south-east.

The division of these farms into two series was entirely accidental, but it has served to indicate that there may be some connection between the acreage grown per farm and the costs of production. Certainly the lowest costs per ton—though not per acre—were obtained on the two farms having the largest acreages under potatoes—44 and 62 ac. respectively—but no definite conclusion on this point can be formed from such a small number of cases.

It will be seen that the average net cost per acre over these twelve farms was £42, 10*s*. 6*d*., and the gross cost £44, 5*s*. 9*d*. The average yield per acre of ware and seed was 8 tons 3½ cwt., so that after crediting the brock at the average rate of £1, 0*s*. 6*d*. per acre and a share of the cleaning costs at the average rate of £1, 14*s*. 5*d*. per acre, the net cost per ton of ware and seed averaged £4, 17*s*. 3*d*., and the gross cost £5, 1*s*. 7*d*.

[1] The principal data contained in this article are taken from the writer's *Report to the Board of Agriculture for Scotland on Financial Results and Costs of Production on 65 Scottish farms for the period ended Whitsunday*, 1921, H.M. Stationery Office.

Acknowledgment is also due to the Board of Agriculture for Scotland for the use of original and unpublished data.

TABLE SHOWING COST OF PRODUCTION OF SCOTTISH POTATO CROP—SEASON 1920

| Series | I. | | II. | | All Farms. | |
|---|---|---|---|---|---|---|
| Number of Farms | 6. | | 6. | | 12. | |
| Acreage per Farm | 24½. | | 6. | | 15⅔. | |
| Factor. | Cost per Acre. | % of Gross Cost. | Cost per Acre. | % of Gross Cost. | Cost per Acre. | % of Gross Cost. |
| | £ s. d. | | £ s. d. | | £ s. d. | |
| Labour: Man | 11 3 1 | 26·5 | 13 6 1 | 25·1 | 11 11 6 | 26·1 |
| Horse | 6 14 10 | 16·0 | 11 4 4 | 21·1 | 7 12 4 | 17·2 |
| Total labour cost | 17 17 11 | 42·5 | 24 10 5 | 46·2 | 19 3 10 | 43·3 |
| Seed | 9 11 3 | 22·7 | 12 12 9 | 23·8 | 10 3 3 | 22·9 |
| Manures—net cost of | 8 16 0 | 20·9 | 11 1 5 | 20·9 | 9 4 10 | 20·9 |
| Rent and rates | 1 14 1 | 4·0 | 1 5 7 | 2·4 | 1 12 5 | 3·7 |
| General expenses | 2 8 7 | 5·7 | 1 16 1 | 3·4 | 2 6 2 | 5·2 |
| Net cost | 40 7 10 | 95·8 | 51 6 3 | 96·7 | 42 10 6 | 96·0 |
| Interest—6 per cent per annum | 0 17 0 | 2·0 | 0 16 0 | 1·5 | 0 16 9 | 1·9 |
| Management | 0 18 0 | 2·2 | 0 19 0 | 1·8 | 0 18 6 | 2·1 |
| Gross cost | 42 2 10 | 100·0 | 53 1 3 | 100·0 | 44 5 9 | 100·0 |
| Yield per acre: ware and seed | 8 tons 9 cwt. | | 7 tons 1½ cwt. | | 8 tons 3½ cwt. | |
| | £ s. d. | | £ s. d. | | £ s. d. | |
| Credit for " brock ", per acre | 1 0 8 | | 1 0 1 | | 1 0 6 | |
| Credit for cleaning costs, per acre | 1 12 8 | | 2 1 10 | | 1 14 5 | |
| Total credits per acre | 2 13 4 | | 3 1 11 | | 2 14 11 | |
| Net cost per ton: ware and seed | 4 9 3 | | 6 16 4 | | 4 17 3 | |
| Gross cost per ton: ware and seed | 4 13 5 | | 7 1 3 | | 5 1 7 | |

There was, of course, considerable variation in the results from the individual farms, and this may be shown as follows:

| | Lowest. | Case No. | Highest. | Case No. |
|---|---|---|---|---|
| Net cost per acre (after deducting credits) | £33, 8*s.* 8*d.* | 2 | £63, 5*s.* 9*d.* | 9 |
| Yield per acre (ware and seed) | 3 tons 16½ cwt. | 1 | 11 tons 7½ cwt. | 4 |
| Net cost per ton (ware and seed) | £3, 17*s.* 4*d.* | 5 | £8, 3*s.* 5*d.* | 1 |

A scrutiny of the individual results shows that it is difficult, with such

a small number of cases, to trace any definite relation between the yield per acre and the cost per ton, or between the cost per acre and the cost per ton. Thus we have the following results—in each case for ware and seed:

| Case No. | Net Cost per Acre. | Yield per Acre. | Net Cost per Ton. |
|---|---|---|---|
| | £ s. d. | | £ s. d. |
| 1 | 33 19 9 | 3 tons 16½ cwt. | 8 3 5 |
| 2 | 33 8 8 | 7 " 12½ " | 4 6 2 |
| 4 | 59 11 11 | 11 " 7½ " | 5 4 3 |
| 12 | 56 18 0 | 7 " 2 " | 7 17 9 |
| 5 | 40 4 7 | 10 " 1½ " | 3 17 4 |
| 9 | 63 5 9 | 9 " 4 " | 6 15 7 |

What was said in the previous article on grain crops applies with even greater force here, viz. where the farmer takes such steps as are generally sufficient to ensure a good crop, i.e. uses carefully selected seed, manures heavily, and cultivates thoroughly, and where the weather or other conditions prevent the development of a full crop, the cost per ton of ware and seed is almost certain to be abnormally high. This is well seen in case No. 12 above. Case No. 4 again shows that where a large crop is obtained a high cost per acre may still result in a moderate cost per ton, while case No. 2 shows that a low cost per ton may result from the combination of a low cost per acre and a moderate yield.

In any case, it must again be emphasized that cost per ton is not a sure index of economic efficiency in crop production. What is wanted is a moderate cost per ton, i.e. a moderate profit per ton, combined with a large turnover, i.e. a high yield per acre, for clearly a 10-ton crop showing a profit of £1 per ton will be preferred to a 6-ton crop with a profit of 30*s*. per ton.

Further, it will be realized that with the newer varieties of potatoes, commanding high prices per ton, abnormally high costs per acre and per ton may still result in abnormally high profits; but should the prices for such varieties fall suddenly (as, for example, Arran Comrade in the year in question) heavy losses are likely to follow. In other words, economic efficiency must be judged not by costs per acre, yields per acre, or costs per ton, but by a consideration of complete cost accounts showing income as well as expenditure, profit per acre as well as profit per ton, and so on.

With regard to the distribution of the gross cost per acre amongst the various factors in production, it will be seen that, on the average, labour, seed, and manures absorbed about 87 per cent of the total, while less than 4 per cent was due to rent and rates. This aspect of the results need not

be further discussed in this article, but attention may be called to the high cost of seed in the season 1920. With seed at about one-half the price, as it was in 1921, the relative importance of the various cost factors would undergo considerable modification.

## Costs of Turnip Crop.

No separate costs for yellow turnips and for swedes can be given, but the data given below refer mainly to swedes.

As already indicated, the turnip crop is the origin of several of the fundamental problems in the costing of individual crops. Not only is it extremely difficult to arrive at the cost per acre, but also it is generally impossible to obtain accurate figures as to yields per acre, since a portion of the crop is usually fed off on the ground. In the data here given the costs have been taken out up to the point at which the crop is handed over to the attendant on live stock, i.e. up to pitting in the fields for sheep, up to carting into the turnip sheds for cattle, or up to putting on to grass fields for either sheep or cattle.

The table on p. 222 summarizes the costs of production of this crop in 1920 on twenty-four farms in various districts of Scotland—four in the west and south-west, fifteen in the east and south-east, and five in the north and north-east.

The average net cost per acre over all these farms was £18, 2*s.* 7*d.*, and the gross cost £19, 12*s.* 7*d.* The yield per acre was not obtained in all cases in Series II, but in Series I it averaged 17½ tons per acre (partly based upon estimate of yield), so that in this series the net cost per ton, after crediting a share of the cleaning costs at the average rate of 20*s.* 11*d.* per acre, amounted to 20*s.* 3*d.* on the average, and the gross cost to 21*s.* 11*d.*

It will be noticed that by far the most important factor in the cost of growing the turnip crop is labour, the cost of which averaged 56 per cent of the total gross cost per acre. Next to labour come manures with 21 per cent, and it may be pointed out that, both in the case of turnips and of potatoes, only the net cost of the manures is included here, i.e. the total cost of the manures applied less the amount credited and chargeable against the other crops in the rotation. It should also be noticed that the differences in the average results of the two series are very small, and since the farms included in the two series were selected at random, this result may not be without significance.

As was to be expected, the variation in the individual farm results is very marked. Thus, in four cases where the crop was entirely or mainly fed off the ground, the net costs per acre amounted to £9, 17*s.* 6*d.*, £11, 11*s.* 7*d.*, £11, 17*s.* 7*d.*, and £15, 5*s.* 9*d.* respectively, whereas in other four cases where the crop was entirely or mainly carted off and fed to cattle the respective net costs per acre were £24, 13*s.* 10*d.*, £29, 0*s.* 5*d.*, £29, 10*s.* 9*d.*, and £31, 3*s.* 11*d.* Taking the nineteen cases in which the

TABLE SHOWING COST OF PRODUCTION OF SCOTTISH TURNIP CROP—SEASON 1920

| Series | I. | | II. | | All Farms. | |
|---|---|---|---|---|---|---|
| Number of Farms | 13. | | 11. | | 24. | |
| Acreage per Farm | 26½. | | 35. | | 30⅓. | |
| Factor. | Cost per Acre. | % of Gross Cost. | Cost per Acre. | % of Gross Cost. | Cost per Acre. | % of Gross Cost. |
| | £ s. d. | | £ s. d. | | £ s. d. | |
| Labour: Man | 6 9 10 | 32·1 | 5 12 11 | 29·6 | 6 0 11 | 30·8 |
| Horse | 4 16 11 | 24·0 | 4 18 9 | 25·9 | 4 17 10 | 25·0 |
| Total labour cost | 11 6 9 | 56·1 | 10 11 8 | 55·5 | 10 18 9 | 55·8 |
| Seed | 0 7 0 | 1·7 | 0 9 5 | 2·4 | 0 8 3 | 2·1 |
| Manures—net cost of | 4 3 8 | 20·7 | 4 0 10 | 21·2 | 4 2 2 | 20·9 |
| Rent and rates | 1 7 7 | 6·8 | 0 19 3 | 5·0 | 1 3 3 | 5·9 |
| General expenses | 1 9 2 | 7·1 | 1 11 1 | 8·1 | 1 10 2 | 7·6 |
| Net cost | 18 14 2 | 92·4 | 17 12 3 | 92·2 | 18 2 7 | 92·3 |
| Interest—6 per cent per annum | 0 16 6 | 4·1 | 0 16 3 | 4·3 | 0 16 4 | 4·2 |
| Management | 0 14 0 | 3·5 | 0 13 6 | 3·5 | 0 13 8 | 3·5 |
| Gross cost | 20 4 8 | 100·0 | 19 2 0 | 100·0 | 19 12 7 | 100·0 |
| Yield per acre—tons | 17·5 tons | | * | | — | |
| Credit for cleaning costs per acre | £ s. d. 1 0 11 | | £ s. d. 1 18 1 | | £ s. d. 1 9 11 | |
| Net cost per ton | 1 0 3 | | — | | — | |
| Gross cost per ton | 1 1 11 | | — | | — | |

* Complete data not available.

yields were obtained, the yield per acre varied from 10·1 up to 30 tons, while the lowest net cost per ton (after deducting a share of the cleaning costs) was 12*s.* and the highest 51*s.*

Apart from the usual causes, the final costs of the turnip crop are affected by two special causes of variation, viz. (1) less labour is required when the crop is fed off on the ground and especially when it is consumed broadcast, i.e. without being shawn and pitted, and (2) when the crop is fed off on the ground a much larger proportion of the cost of the manures applied must be charged to other crops in the rotation than when it is carted off. In fact, data of costs per acre or per ton for the turnip crop are particularly meaningless unless accompanied by a definite statement as to the point up to which the costs have been taken,

### Other Root Crops.

The procedure in costing other root crops—mangels, kohl-rabi, sugar-beet, carrots, parsnips, cabbage, kale, rape, &c., the term root crops being used in a conventional sense—is very similar to that for potatoes and turnips. The actual costing work, however, is often complicated, especially in Scotland, by the fact that these crops are commonly grown in small patches in fields which are mainly devoted to potatoes or turnips. For one thing, this requires careful measurement of these patches, since an error of $\frac{1}{4}$ ac. in a 2-ac. plot would lead to a considerable error in the yields and costs per acre; for another, the recording of the man and horse labour expended upon such small plots involves extra care to see that the actual times are given—small plots will often result in more broken time.

One further point may be briefly referred to here, and what is said applies to turnips and potatoes as well as to other root crops: what should be the procedure in the event of a root crop proving a total or almost total failure?

In the first place, a crop of turnips, say, may be successfully started on its way when it is attacked by the finger-and-toe disease, with the result that the crop ultimately harvested is an extremely small one, perhaps only three or four tons per acre, and is also of poor feeding quality. As ordinarily figured, the cost of such a crop per ton is, of course, abnormally high, and, if the cost of production principle be followed, it will be charged at this price to the live stock by which it is consumed. In other words, the loss due to the partial crop failure will be transferred *in toto* to the live stock department.

In the second place, it often happens that a root crop fails completely quite early in the season, and the land is ploughed up and sown with a different crop, e.g. turnips after cabbages, rape after turnips. Here the question arises: what is to be done with the costs incurred upon the crop which has failed, i.e. for those operations and materials which will be of no benefit to the second crop? It would be obviously illogical to charge the whole season's costs against the latter crop, and it would be equally so to follow the suggestion which has been made that such losses as the above should be carried direct to the profit-and-loss account and not included in the cost accounts at all—the average cost of growing any crop must take account of the " misses " as well as the " hits ", of the " outers " as well as the " bulls ".

These questions raise an important issue in farm costing, especially with reference to the determination of separate crop as against complete rotation costs. The most obvious solution, in principle at any rate, would be to form a " reserve fund for crop failures " account for each crop. During good seasons and with good crops an addition to the costs would

be made to represent a sort of insurance fund against such failures as have been mentioned above, while during unfavourable seasons and with complete or partial failures this reserve account would be drawn upon and the costs, as ordinarily calculated, would be reduced.

This, of course, is no more than a modification of the well-known "equalization of dividends" principle, but in the present state of the organization of the farming industry it is doubtful whether such a procedure would be practicable, however great, from a costing and farm-management point of view, the need for it may be. The main objection no doubt is that it would be very largely a matter of opinion or of judgment how much should be carried to and from the reserve fund account for any crop and in any year. But the final results from the adoption of such a principle would be at least less ludicrous than those obtained by charging against live stock a crop of turnips from a 10-ac. field which yielded only 30 tons altogether at the actual cost of production of, say, £150 or £5 per ton!

With regard to the costs of production of root crops other than potatoes and turnips, the available data are extremely scanty. One reason for this state of affairs has already been indicated, and may be exemplified from the experience of the Agricultural Costings Committee in Scotland. On fifty-six farms scattered throughout Scotland, about one-half of which was arable land and the other half permanent pasture, a total of 2380 ac. of root crops was grown in the year 1920. Of this total 110 ac. were under rape, 9 ac. under mangels, 7 ac. under cabbages, 5 ac. under sugar beet, 3 ac. under kale, and 1 ac. under carrots; i.e. less than 1 per cent of the total acreage of these farms was under "other root crops" compared with 13½ per cent under potatoes and turnips.

As regards rape, three typical cases may be quoted for crops grown and eaten off by sheep in 1920. In the first, the gross cost per acre was £8, 1*s.*, in the second, £6, 9*s.* 3*d.*, and in the third, £7, 10*s.* 8*d.*, or an average over the total acreage on these farms of £7, 9*s.* 3*d.* The costs obtained under this scheme for any of the other root crops relate to far too small acreages to have any real significance and need not be given here.

It is unfortunate that at the time of writing no further data, based upon systematic cost accounts kept upon the principles which have been enunciated in this and in the previous article, are available.

Some useful data are contained in Orwin's *Farming Costs* and in an article on the cost of production of sugar beet in England by Orwin and Orr which appeared in the *Journal of the Board of Agriculture and Fisheries* for Feb., 1915, but these data are for different years and are not strictly comparable with those already given.

# DISEASES OF ROOT AND POTATO CROPS

By D. G. O'BRIEN, M.A., B.Sc., B.Sc.(Agric.), N.D.A.

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## DISEASES OF ROOT CROPS

With the exception of potatoes, root crops in cultivation in this country belong to three natural orders, viz. Cruciferæ (cabbages, turnips, swedes, rape, kale, and kohl-rabi), Chenopodiaceæ (mangels and sugar beet), and Umbelliferæ (carrots and parsnips).

A considerable number of plant diseases affect, in varying degrees, many members of the cruciferous order. For instance, the fungus *Plasmodiophora brassicæ*, which causes the disease known as finger-and-toe in turnips and swedes, is parasitic upon, and pathogenic to, other crops and weeds of the same order. Similarly the diseases affecting the mangel occur on other members of Chenopodiaceæ.

It will therefore be convenient to treat general diseases such as these under one heading. At the same time it may simplify matters if, to begin with, a summary of the diseases affecting each crop is given along with a reference showing the title under which each disease is described.

### Diseases of Turnips and Swedes

1. Finger-and-toe: see p. 226.
2. Black Rot: see " Black Rot of Cruciferous Plants ", p. 234.
3. Mildew: see " Powdery Mildew of Cruciferous Plants ", p. 233.
4. False Mildew: see " Downy Mildew of Cruciferous Crops ", p. 232.
5. White Rust: see p. 232.
6. White Rot: see p. 229.
7. Soft Rot: see " Soft Rot of Carrots ", p. 238, also " White Rot ", p. 229.
8. Sclerotium Disease: see p. 237.
9. Dry-rot: see " Phoma Rot ", p. 236.
10. Crown Gall: see *Pseudomonas tumefaciens*, E.F.S., p. 235.
11. Scab: see p. 232.
12. Rhizoctonia: see p. 237.

### Diseases of Cabbages, Rape, Kohl-rabi, and Kale

1. Club Root: see "Finger-and-toe", p. 226.
2. Black Rot: see "Black Rot of Cruciferous Plants", p. 234.
3. Mildew: see "Powdery Mildew of Cruciferous Plants", p. 233.
4. False Mildew: see "Downy Mildew of Cruciferous Crops", p. 232.
5. White Rust: see p. 232.
6. Sclerotium Disease: see p. 237.
7. Root Rot: see "Phoma Rot", p. 236.
8. Soft Rot: see p. 238.
9. Scab: see p. 232.
10. Crown Gall: see p. 235.
11. Rhizoctonia: see p. 237.

### Diseases of Beet, Sugar Beet, and Mangels

1. Beet Mildew (*Peronospora Schachtii*): see p. 232.
2. Leaf Spot (*Cercospora beticola*): see p. 230.
3. White Rust (*Albugo candida*): see p. 232.
4. Leaf Rust: see p. 230.
5. Dry Rot (*Phoma*): see p. 236.
6. Curly Top: see p. 231.
7. Scab (*Actinomyces scabies*, Thaxter.): see p. 232.
8. Sclerotium Disease: see p. 237.
9. Crown Gall: see p. 235.
10. Rhizoctonia: see p. 237.

### Diseases of Carrots

1. Soft Rot: see p. 238.
2. Sclerotium Disease: see p. 237.
3. *Phoma rostrupii*, Carrot Disease: see p. 236.
4. Rhizoctonia: see p. 237

**Finger-and-toe, Club-root, Anbury, or Canker.**

This disease has been known to attack the cabbage family (Cruciferæ) since 1736, in which year it was referred to as occurring in England. Its ravages then would seem to have been comparatively mild, and it was not until about a century later that it assumed serious proportions and was noted as being practically world-wide in its distribution.

The disease is described as finger-and-toe when it affects turnips and swedes, while the names club-root, anbury, and canker are variously applied to it when cabbages, kale, kohl-rabi, cauliflower, and Brussels sprouts are attacked. Cruciferous weeds such as Shepherd's Purse, Runch, and Charlock are likewise susceptible and provide a means of perpetuating the trouble on land where cultivated plants of this order are infrequently grown.

Infected plants can be readily recognized by the enlarged growths or knob-like swellings (fingers and toes) found either on the main roots or lateral roots or on both. Outgrowths of a different type which might be confused with this disease may be caused by the irritating action of certain eel-worms or insects. The former give rise to more or less round root knots or galls which are considerably smaller in size, while in the latter case the larvæ of certain insects, e.g. Turnip-gall Weevil (*Centorhynchus sulcicollis*), which are parasitic upon the roots of cabbages, turnips, &c., cause the formation of small round galls about the size of a pea or marble. When cut open such insect galls show a larva in the centre of each swollen area.

*Cause.*—The responsible organism is known by the name *Plasmodiophora brassicæ*, Wor., which is generally classed with the myxomycetes or slime-fungi.

*Symptoms.*—The swellings already referred to are at first small. As the disease progresses they rapidly increase in size, often attaining the dimensions of a man's hand. A sectional cutting of a diseased area in the early stages discloses solid tissue of greyish colour, mottled with small, white, opaque patches; later the swellings become brown and decay.

The nature of the resulting decay varies with the soil type; in light sandy soils the putrefaction is rapid and gives rise to a dry, powdery residue, while in heavy, clay soils the product is of a semi-liquid character and is distinctly unpleasant in odour.

Turnips affected with finger-and-toe, owing to their root injuries, are nearly always found to rot to a greater or lesser extent. Organisms that produce such rotting gain a ready entrance into the plants through these injuries.

The primary roots are often almost completely destroyed, in consequence of which affected plants can be easily pulled up. An attempt is generally made by such plants to form adventitious roots, but these in turn may become invaded by the fungus and suffer a similar fate.

The supply of soil water is seriously or, it may be, completely interrupted, and wilting of the foliage, especially in dry, warm weather, occurs. The wilting is permanent and is not to be confused with temporary wilting due simply to climatic conditions. In both cases, of course, the limp appearance is the result of the failure, temporarily or permanently, of the roots to supply sufficient moisture to compensate for the loss by transpiration from the leaves.

Most of the nutriment manufactured in the green leaves goes either to maintain the fungus or to form the swollen roots; hence in the case of turnips and swedes little healthy growth takes place, while cabbages and cauliflowers are much dwarfed and form practically no " heads ".

*Microscopic Appearance.*—Under the microscope the root swellings,

when fresh and undecayed, show, distributed throughout the small cells of the cortex and medulla, many larger cells filled with frothy, turbid, brownish protoplasm. These represent the vegetative part of the organism —the plasmodium. The plasmodium develops at the expense of the plant and eventually divides into a very large number of small, round, thick-walled spores which are set free in the soil on the decay of the root.

The spores can remain dormant in the soil for a considerable period. However, when conditions suit, they germinate, each spore giving rise to an actively moving protoplasmic structure which afterwards develops into a creeping amœba-like body, termed a myxamœba. These enter the roots of susceptible plants, probably through the root hairs, and pass from cell to cell. Living on the cell contents, they cause the frothy mixture already described.

Soil temperature is a predisposing factor to the onset of the disease. In spring and early summer the organism is comparatively inactive; attacks about midsummer are much more virulent and widespread.

*Control Measures.*—As the spores or the myxamœba can persist in the soil for at least three years, close cropping with susceptible cruciferous plants should be avoided. That, in short, means that a lengthening of the normal rotation will tend to starve out the organism. This can often be conveniently done by taking a crop of potatoes in place of either the whole or part of the usual turnip crop. The latter probably best suits most circumstances and allows of a reversal of the positions of the potato and turnip crops when the land is once more under green crop.

It would appear from certain evidence that the potato crop produces some substance which has a deleterious effect upon the fungus causing finger-and-toe.

To be completely effective this method of control must be accompanied by the rigorous extermination of all cruciferous weeds which are likely to harbour the disease.

The organism seems to thrive best in a soil deficient in lime—otherwise described as a sour or acid soil. Any methods of soil treatment, with a view to arresting or eradicating the disease must aim at correcting these conditions. Draining may be a fundamental necessity and may in certain instances require to be undertaken, but liming in addition, or alone, is indispensable as a means of neutralizing the sourness or acidity.

Quick or freshly slaked lime should be applied as long before the turnip or other cruciferous crop in the rotation as possible. The following are convenient times for application: (*a*) on the ploughed redland following the previous cruciferous crop, or (*b*) ploughed in prior to the preceding cereal crop. At least a period of twelve months' thorough admixture with the soil is essential if appreciable results are to be expected.

The quantity of lime to apply should vary according to the severity of the attack and the acidity of the soil, but as a rule a heavy dressing of 3 to 4 tons per acre is advisable. Any local spots where the disease is known to be particularly prevalent should receive an additional allowance.

It will be found effective to withhold farmyard manure from the cruciferous crop and to rely on basic or neutral manures for fertilizing purposes. Of the phosphatic manures basic slag is to be recommended, while superphosphate should only be employed to a very limited extent.

Farmyard manure will always tend to be contaminated with the spores of the disease whenever a diseased crop is fed to stock or when, as frequently happens, the sweepings of the root store are consigned to the manure heap.

When a small acreage is devoted to the crop it might be feasible to remove all diseased plants at intervals during the growing season.

The various cultivated cruciferous crops show marked variation in their susceptibility to this disease, and, furthermore, varieties of the same crop may be similarly graded. Cauliflowers and Brussels sprouts are particularly affected, whilst the kales, including Thousandhead Kale and Marrow-stem Kale, possess a certain degree of resistance. There is considerable variation between the varieties of turnips and swedes; of the latter the most resistant on the market at present is the Danish variety known as Bangholm.

There is obviously quite a field in front of the plant breeder to produce strains of the different cruciferous plants capable of withstanding the ravages of this disease. New varieties of this nature offer the surest means of completely stamping it out.

In the case of such crops as cabbages, which are generally grown from transplanted seedlings, care must be taken to avoid contamination either through the soil or any manure or refuse used. Further, during transplanting, any plants showing symptoms of the disease should be rejected.

**White Rot.**

Common among turnips and swedes, this disease is characterized by the interior of the root becoming soft, pulpy, and rotten.

*Cause.*—The disease is bacterial, and the particular organism has been described by Potter as *Pseudomonas destructans*. It seems probable, however, that this may be the same organism that has been isolated as the cause of soft rot in carrots (see p. 238). *Bacillus carotovorus*, which is the name applied in the latter case, has also been diagnosed as affecting other crops, such as turnips, swedes, and parsnips, and would appear to be closely related to *B. phytophthorus*, which causes black rot in potatoes.

*Symptoms.*—The leaves of affected plants wilt and turn yellow, and finally drop off. The outside leaves are first affected, but soon the trouble becomes evident on the younger foliage parts. In two or three weeks' time the inner tissues of the root break down into a soft mass with a somewhat disagreeable odour.

The organism apparently gains entrance to the plant through wounds.

*Preventive Measures.*—By far the greatest loss results to stored roots. In this connection it has been shown that good ventilation, as a means of keeping down the temperature, is the most effective method of checking pit troubles. A fairly high temperature is essential for all rotting organisms.

It is a good plan, if the weather permits, to leave the roots lying for a few days before pitting or storing in any way. Reasonable care should also be taken during lifting and storing to avoid damaging the roots.

### Beet Rust (Leaf Rust).

This disease is of frequent occurrence on garden and sugar beet, and on mangels. It affects the leaves of these, and by diminishing the rate of carbon assimilation restricts the root development.

It was known in Europe in 1869, and has since been diagnosed as a fungoid disease caused by the organism *Uromyces betæ*, Pers.

In the life cycle of this disease three types of spores are produced: (*a*) æcidiospores in spring and early summer, (*b*) uredospores in summer, and (*c*) teleutospores in autumn.

Æcidiospores are rarely met with except on the young leaves of beets kept over the winter for seed-production purposes. They are in the form of cluster-cups and appear as limited yellow spots.

Uredospores are produced in large numbers and occur as small brown patches scattered over the whole leaf on the upper and lower surfaces. These germinate at once and spread infection to neighbouring plants.

Teleutospores arise in the patches where the uredospores are produced earlier in the season. The diseased areas at this stage are dark brown in colour.

*Control Measures.*—Those advocated are as follows:

1. Removal of all leaves bearing the spring stage of the fungus.
2. The isolation of seed beet from the regular crops of mangels and sugar beet.
3. Spraying with Bordeaux mixture (see under "Potato Blight").
4. The destruction of all leaves in autumn which show the disease.
5. Avoiding contamination of the farmyard manure with decayed roots, leaves, or other refuse.

### Leaf Spots.

A disease known as cercospora leaf spot is found on the leaves of garden and sugar beet and mangels. It is especially injurious to the

leaves of sugar beet, and spreads most rapidly during dry, warm weather.

The fungus causing this form of leaf spot is named *Cercospora beticola*, Sacc.

*Symptoms.*—Round, brownish, purple-bordered spots are scattered over the blades of the leaves. The brown colour of the spots, especially at their centres, takes on an ashen grey and finally a black hue. The affected parts dry up, become brittle, and drop out, leaving ragged holes. The outer leaves are affected first, but the inner ones soon become involved.

These spots may cause the destruction of the greater part of the leaves, and in some cases the whole leaf may die, leaving its black remains standing nearly upright upon the crown of the bulb. Frequently the death of the older leaves causes the crown to elongate, suggesting the name "pine-apple disease". This elongation of the crown is due to an attempt on the part of the plant to produce fresh leaves in the centre to replace the outer ones which have been destroyed.

When badly attacked the power of a plant to produce a bulb is seriously impaired.

*Control Measures.*—

1. Affected parts of a field may be sprayed with Bordeaux mixture (1 per cent).
2. All affected leaves should be destroyed.
3. It is important that plants to be used for seed purposes should bear no traces of the disease.
4. A lengthening of the time between successive crops of susceptible plants is advisable.

Some varieties are more resistant than others to this disease. Investigation in this direction probably offers the largest scope for dealing with the disease in future.

**Curly Top of Sugar Beet.**

Unlike cercospora leaf spot, this disease first asserts itself on the inner leaves of the plant. The leaves curl inwards from the entire margin towards the midrib, and the veins become knotted on the dorsal surfaces. Affected plants are stunted in growth in all parts, the petioles especially being short and bent.

The roots, which are tough and sometimes show a black interior cavity, develop an abnormal number of fine rootlets; hence the common name for the disease, "hairy root".

In sugar beet growing areas the loss is very extensive, as not only are the roots small but they contain a low percentage of sugar.

Little is known as to the cause of the disease, but it has been proved

to be communicable by grafting, and in America a leaf hopper, *Entellix tenella* by name, is found to be capable of transmitting it from a diseased to a healthy plant.

### Downy Mildew of Cruciferous Crops.

This disease attacks cabbages, turnips, swedes, rape, and other cultivated and wild cruciferous plants. Though the damage done is insignificant in the field, yet occasionally in the seed-bed relatively great loss may be sustained.

*Cause.*—The causative organism is the fungus *Peronospora parasitica* (Pers.), de Bary.

*Symptoms.*—Yellowish white flour-like (downy) patches are found on the stem and on the lower surface of the leaves. These spots viewed from above are more or less angular and are limited by the veins. The tissues of the affected part also appear somewhat sunken.

*Control Measures.*—The most effective means of checking this pest is to spray with Bordeaux mixture (2 to 3 per cent).

All diseased plants should, wherever feasible, be burned.

### Beet and Mangold Mildew.

This disease, caused by *Peronospora Schachtii*, Fuekel, is responsible for considerable damage to mangold and sugar beet. The young central leaves are invaded by the fungus. At first affected leaves are pale with curled or rolled-back edges, but mature leaves are pulpy and swollen with a profuse growth of grey or yellow mould on the under surface. The leaves of badly affected plants soon die. Occasionally rotten spots appear on the bulbs. If slightly diseased plants are propagated for seed the fungus persists over the winter on the leaves and is present on the seeded plant. Control measures are similar to those advocated for downy mildew on cruciferous plants.

### Beet and Mangold Mildew (White Rust).

This disease affects cruciferous plants in general, but is only really injurious to radish and to the weed Shepherd's Purse. Cabbages, swedes, turnips, and rape may occasionally be slightly affected.

White rust is caused by the fungus *Albugo candida*, Kuntz (= *Cystopus candidus*, Pers.), whose genus, Albugo, is closely related to Peronospora.

Another species, *Albugo bliti* (Bir.), Kuntz, is found on the leaves of sugar beet and mangels.

### Scab (*Actinomyces scabies*, Thax.).

A form of scab occurs on the roots of beet, sugar beet, mangels, turnips, and cabbages. The organism causing the disease is believed to be the same

as that which produces common scab on potatoes, namely, *Actinomyces scabies*, Thaxter.

The surface of the roots is covered more completely with scab than in the case of the potato, and there is a tendency to form corky growths instead of giving rise to deep cavities.

A lengthening of the rotation is the most practicable method of prevention.

## Powdery Mildew of Cruciferous Plants.

The term " mildew " is often loosely used. It is adapted to include all forms of discoloration occurring in small spots, and no distinction is made as to the causative fungi, which often differ very widely in their generic characters.

Phytopathologists, however, distinguish two kinds of mildew: (*a*) powdery mildew, caused by members of the Erysiphaceæ family, and (*b*) downy or false mildew, caused by the Peronosporaceæ. Of the two kinds of affection the former is the more severe.

Powdery mildew attacks turnips, swedes, rape, and other species of cruciferous plants. The mycelia of the fungus grow over the surface of the leaves in the form of a white cobweb-like growth and send short suckers, called haustoria, into the leaf tissues. Although the greater part of the fungus is external, yet these haustoria withdraw so much nourishment from the cells as to cause injury to the host plant.

During summer the fungus propagates by asexual conidia which occur in chains borne on a stalk or conidiophore. These conidial forms were at one time considered to be distinct fungi and were referred to as species of the genus Oidium. This generic name has been retained to designate those species of Erysiphe in which the production of the sexual spores (ascospores) has not yet been seen.

*Cause.*—Powdery mildew in cruciferous plants is caused by the fungus *Oidium balsamii*, Mont., which is an unclassed member of the Erysiphaceæ. Some, however, designate it *Erysiphe polygoni*, but it is doubtful if this nomenclature is correct.

*Symptoms.*—The mycelium may spread over the whole plant and produce enormous numbers of spores (conidia) which cover the plant with a mealy or chalky looking powder. The clothes and boots of anyone walking through a field of affected turnips or rape take on a similar covering, due to the adhering conidia.

The fungus is found chiefly on the under surface of the leaves and on the leaf stalks. In some cases distortion of affected parts may be seen.

Diseased plants when eaten have been known to cause poisoning of sheep.

### Black Rot of Cruciferous Plants.

The cause of this disease is a bacterium known as *Pseudomonas campestris*, Pammel. Most damage is done to the cabbage crop, in which it sets up what is known as black rot or brown rot; but it occurs also on kale, broccoli, kohl-rabi, Brussels sprouts, turnips, swedes, rape, black mustard, charlock, and other members of the same family.

It is stated that cruciferous plants with rape " blood " are most susceptible to this disease, and that those less closely allied are fairly resistant. This would point to rape as being the least resistant to black rot.

*Infection.*—The causal organism gains access to the droplets of water found, especially in damp, warm weather, at the water pores on the edges of the leaves, and from there passes through the pores into the vascular bundles. Occasionally the organism enters from the soil into the plant through wounds in the root.

*Symptoms.*—In the case of cabbages the disease usually makes itself apparent first on the lower leaves in the form of pale yellowish green areas near the margins. As the trouble progresses the affected patches increase in size and become brown, and if the leaves be held up to the light the veins appear dark brown or blackish in colour. In a plant badly attacked the blackening of the veins can be traced back into the stem, and from there, upwards and downwards, to other leaves. Usually many leaves are infected simultaneously.

Affected leaves wilt and turn yellow owing to the choking of the vascular strands with a brownish substance teeming with the disease organisms. Later on they become dry and parchment-like and fall to the ground. If the attack is particularly bad the plant may ultimately die or, if it survives, it will be stunted in growth and produce only a rudimentary head.

As is usual in many other plant diseases, the partially decomposed tissues are frequently invaded by secondary organisms which set up various forms of putrefaction, with the production of unpleasant odours.

When turnips or swedes are affected by black rot the leaves show a similar progression of symptoms until the disease makes itself evident in the bulbs. The surface flesh appears comparatively clean, but below the skin darkened areas arranged either radially or longitudinally occur, while the vascular bundles are likewise of blackish colour. The whole inside of the bulb finally changes into a slimy, fetid mass, due in many cases no doubt to secondary infection with putrefactive micro-organisms.

The bulbs of affected plants do not develop normally but remain long and thin like carrots. When pitted or stored they may set up an extensive rotting and serve to infect other healthy specimens.

*Control Measures.*—The trouble can be combated to a certain extent by lengthening the interval in the rotation between susceptible cruciferous

CROWN GALL ON SUGAR BEET

*Facing p. 234, Vol. II*

crops. During this time, however, it is important that weeds belonging to the same order should be kept down.

Infected plants should, where practicable, be removed as soon as noticed from the growing crop and burned. The use of such plants for feeding purposes is inadvisable, as they serve to propagate the disease through the dung heap.

Considerable evidence has been adduced to show that the disease may be seed-borne in the case of cabbages. As a precaution the seed may be soaked for fifteen minutes in a solution made up in the proportion of 1 teaspoonful of formalin to $\frac{1}{2}$ pt. of water. This is sufficient to destroy any of the bacteria that may be adhering to the seed.

Observations indicate that some varieties of cabbage and, doubtless too, of turnips and swedes are comparatively resistant to black rot.

Care should be taken in transplanting cabbages not to injure the roots, as wounds of this nature increase the possibilities of infection. This, however, does not, from a survey of the disease, appear to be the usual method by which the disease is contracted.

### Crown Gall or Plant Cancer.

This disease is not a very serious one in so far as damage or loss is concerned, but owing to its prevalence on many different hosts it must be mentioned.

It is caused by the crown gall bacillus, otherwise *Ps. tumefaciens*, which is parasitic upon a great variety of cultivated and wild plants. The organism locates itself at a particular spot where, as the result of cell irritation, it gives rise to an excessive local growth. A tumour is formed which consists of a mass of actively dividing round or spindle-shaped cells.

Often this gall or cancerous outgrowth is larger than the shoot or root which bears it. The heaviest specimen on record weighed 96 lb., but one has also been described as measuring 26 in. long by 4 ft. 7 in. broad. The latter was probably still heavier.

The gall sometimes readily decays, but in certain cases it remains hard and resistant. Its effect is to slowly dwarf the structure to which it is attached, either ultimately killing the affected branch or the whole plant.

Galls commonly occur on the trunks of fruit-trees at the ground surface, i.e. on the crown, or on any part of the root or shoot. They have also been located on potato, cabbage, cauliflower, turnip, swede, sugar beet, mangel, and carrot plants.

It seems probable that the diseases known as beetroot tumour and crown gall of lucerne are caused by this organism, and not, as formerly diagnosed, by the fungi *Urophlyctis leproidea* and *Urophlyctis alfalfæ*.

### Root Rot or Phoma Rot.

Several species of fungi belonging to the genus Phoma are parasitic upon, and cause a rotting of, the roots of certain crops. Beet and mangels are attacked by *Phoma betæ*, turnips and rape by *Phoma napobrassicæ*, carrots by *Phoma rostrupii*, and cabbages by *Phoma oleracea*.

Since the symptoms vary to some extent on the different hosts, the above crops are discussed in the order named.

1. *Beet and Mangels*.—Known as heart rot of beet, the disease is characterized by the appearance on the surface of the bulbs of shrunken discoloured areas which bear small black spores called *pycnidia*. The underlying flesh soon becomes black in colour, and the affected area progresses inwards until practically the whole bulb is involved and converted into brown, dry tissue. The decay is a typical dry rot and is not accompanied by any disagreeable odour.

The leaves are affected in a similar manner. Large black circular spots develop first on the inner and later on the outer leaves. The result generally is that the foliage is partly or wholly destroyed.

Heart rot is worst in dry seasons or, alternatively, when very dry weather obtains in July and August. Its ravages are not confined to plants well advanced in growth, but may also occur on seedlings, in which case it causes " damping off ".

2. *Turnips and Rape*.—Small dark spots appear round the neck of the root or bulb. These affected areas spread downwards and inwards, and may involve the destruction of the whole root in the ground. On the other hand an affected root may be only partly diseased and, as a consequence, may in store or pit be responsible for the setting up of fairly extensive rotting.

The decay that ensues, both during growth and storage, is a typical dry rot; hence the name for the disease—dry rot of rape or turnips.

3. *Carrots*—Carrot disease, as this form is called, shows itself towards the end of summer on the crown of the root, or on the top of the root just below the ground surface. Greyish coloured depressions are produced which increase in depth and finally destroy the flesh. As in the preceding cases much damage may be done in the pit by the presence of diseased roots.

4. *Cabbages*.—The disease is known as cabbage canker, and may take several forms according to the stage of development of the plants when attacked. During early growth the soft parts of the root, after invasion, are destroyed, and the plant dies. An attack later in the season may be overcome by the production of a number of fibrous roots above the affected part. Such plants, however, bear stiffer and straighter leaves than they would normally have, which generally very soon afterwards droop and wilt. On this account the name " epilepsy " is given to the disease.

Sometimes symptoms are only evident after the cabbages have been lifted and stored. Inside the stalk of an affected cabbage small spots, at first white, then pale grey, can be seen. These increase in area and the external leaves quickly become attacked. The rotting then extends inwards towards the centre, and the resulting dead leaves gradually drop off from the stalk.

*Control Measures for all Forms.*

1. Remove and destroy before lifting time, and subsequently from the stored roots, all affected plants.
2. Lengthen the rotation and avoid growing susceptible crops except at as long intervals of time as possible.
3. Strains should be selected capable of resisting the attack of the specific fungus.

## Rhizoctonia Disease, Stem Rot, Root Rot.

A great variety of plants are attacked by the fungus *Rhizoctonia* (= *Corticum vagum*, B. and C.). No particular preference seems to be shown by it in this respect as its ravages extend through many widely differing natural orders—Caryophyllaceæ, Cruciferæ, Leguminosæ, Solanaceæ, Compositæ, &c. Among root and forage crops other than potatoes it attacks sugar beet, mangels, carrots, cabbages, turnips, and swedes. It is also a common cause of damping off of young seedlings of many different plants.

The fungus usually affects the roots of plants at or near the ground surface. On the roots there appears a very fine cobweb-like growth, pale or reddish violet or brownish in colour, often barely visible when the plants are uprooted. This network gradually becomes more compact and spreads over the entire root or bulb. Blackish coloured sclerotia can be seen attached loosely to the root. A closer examination of these sclerotia shows that they are connected to the tuber or bulb by a dumb-bell neck which buries itself in the tissues of the host.

There is a considerable difference of opinion as to the damage done to roots by an attack of Rhizoctonia. The fungus is credited by many with causing a form of stem or root rot, serious in the case of young sprouting plants; by others this is disbelieved. Possibly if it does not of itself cause rotting it may, by surface wounds produced, render a plant an easy prey to other fungoid pests.

## Drop on Cabbages, Root-crop Rot, Sclerotium Disease.

The fungus *Sclerotinia sclerotium*, Mass., described as the cause of stalk or sclerotium disease of potatoes, may also do considerable damage to other widely varying types of plants. Of the latter the following are the most important: turnips, swedes, cabbages, rape, mangels, sugar

beet, and carrots. Perhaps it is true, as some authorities suggest, that a greater number of different families of plants are attacked by this fungus than by any other.

On root crops it appears usually on the tuber or bulb in the form of a copious white cotton-wool-like growth which extends rapidly until the whole surface is more or less covered. In some cases a similar growth can be observed on the stems and leaves.

From the exterior the fungus passes into the underlying tissues, and typical black sclerotia—the resting or hibernating stage of the organism—are formed a little below the surface. These vary from the size of a pea to that of a bean, and are capable of persisting as such for a number of years. Ultimately, when conditions are suitable, they germinate and produce spore cups from which smoke puffs are emitted at frequent intervals (see "Sclerotium Disease" of Potatoes, p. 266). In this way the disease is carried over from year to year.

The spread of the fungus is favoured by dampness, and is most noticeable in stored tubers and bulbs, especially when straw has been used for covering purposes. It is generally at this stage that most damage is done, as infection is transmitted from root to root and a considerable amount of rotting takes place.

When cabbages or rape are attacked the outer or older leaves wilt and droop, and eventually fall off. Infection, however, soon spreads until the plants are completely involved. Black rot, which is somewhat similar, may be confused with this disease, but the latter can be distinguished by the cotton-wool-like mycelial growth upon the under sides and at the bases of the leaves. Also in the latter case the black sclerotia may be seen, later on, scattered in this felted mass.

*Protective Measures* would consist of: (*a*) rejecting all diseased bulbs at lifting time; (*b*) properly ventilating the pit or store; (*c*) covering the pit first with a little earth, then with a layer of dry straw, and finally with earth.

The disease obviously is difficult to eradicate, since it attacks so many different host plants and can persist in the soil, probably as a saprophyte on decaying vegetable matter, for a considerable length of time.

### Soft Rot of Carrots.

Soft or wet rot of carrots is caused by the organism *Bacillus carotovorus*, Jones. Much injury may be done in the field, but the greatest loss occurs during the storage of the harvested roots.

Other root crops, namely turnips, swedes, parsnips, and cabbages, are susceptible to the disease. In this connection it is noteworthy that E. F. Smith suggests that the organism to which the disease is ascribed is identical with *Pseudomonas destructans* and *Bacillus phytophthorus*, which

are the causes, respectively, of white rot in turnips and blackleg in potatoes (see p. 249).

The organism seems to enter the plant through wounds on the root, generally at the crown or root tip. Soon afterwards a water-soaked translucent area can be observed round the seat of infection. The invaded tissues break down, and a greyish coloured fluid issues from the affected part.

The rotting, which is aptly described in the name of the disease, rapidly proceeds inwards. As a rule the core rots more quickly than the outside of the bulb, a hollow centre thus often resulting.

*Preventive Measures.*

1. Root injuries should, when harvesting, be avoided as far as possible.
2. Drying the roots in sunlight before storing reduces damage.
3. Storage of the roots under cool conditions—not more than 50° C.—is also effective. The ventilation of the pit should, in this respect, be thorough.

## POTATO DISEASES

The potato is subject to a large number of diseases. This is no doubt partly due to the method employed in propagating the crop. Unlike practically all other agricultural crops its true seeds, namely those maturing from the fertilized flower, are sown only when the object is to produce a new variety. This step accomplished, the variety, whatever it be, is perpetuated by an asexual process in which the tuber is the connecting link between successive crops.

The tuber is simply part of the underground stem. Its use for propagative purposes gives rise to no new generation of plants, but is, in reality, a natural adaptation by which the parent plant is preserved from season to season. The term seed, as applied to a tuber or part of a tuber, is therefore a misnomer, although in view of its popular usage by growers, no attempt to discriminate is made in the following notes on diseases.

A tuber carries the weaknesses of its type, and in successive crops tends to multiply and intensify the various diseases to which it is prone. Besides the purely tuber diseases it in many cases harbours parasitic fungi which attack other parts of the plant. Such fungi at this point are said to be in their resting or hibernating stage. Thus the planting of infected seed is often the essential step in promoting diseases whose harmful effects are only evident on other parts of the plant.

The growing of potato crops in close succession, as, for instance, in market gardens or allotments and in the early potato districts, is a further reason for the prevalence of disease. In the former case there is as a rule no attempt made to practise a system of crop rotation, while in the latter the favourable soil and climatic condition allow of potato crops being

repeated annually or biennially. In ordinary agricultural practice the crop is grown only once during a rotation, or at intervals of from four to eight years.

It is quite to be expected that the extent to which close cropping can be practised in future will be largely determined by the measures taken to combat the various diseases affecting the crop.

In dealing with potato diseases no attempt has been made to treat them in order of importance. Opinions widely differ as to the relative severity of the various diseases. Probably this arises from the fact that the effect of any particular disease varies with the conditions under which the crop is grown. Such variations are local as well as national. It has therefore been considered advisable to discuss the diseases seriatim.

### Potato Disease or Blight.

This disease seems to have originated in South America, and from there to have been carried to Europe about 1840. It increased very rapidly in Europe, soon becoming widespread, and indirectly caused much suffering and loss of life. The famines in Ireland in 1845 and 1848 were directly attributable to the more or less complete failure of the potato crops in these years due to the prevalence of blight.

*Loss.*—Blight is now generally regarded as the most serious disease with which the potato grower has to contend. Orton estimates that in America it causes an annual loss of 36 million dollars. Possibly in Great Britain and Ireland the average annual loss is not far short of 20 per cent of the total crop. Taken on this basis an annual monetary loss of £5,000,000 is not improbable, and in certain seasons the loss must be considerably greater.

*Cause.*—The disease is caused by the fungus *Phytophthora infestans* (Mont.), de Bary, a fungus belonging to one of the divisions of the lower fungi (Phycomycetes).

*Symptoms.*—The appearance, in late summer, of small spots near the tip or margin of the leaflets is the first external manifestation of the disease. These spots subsequently increase rapidly in size and become dark brown or almost black. For a time the darkened areas are surrounded by a narrow light green margin, and if the weather be wet and warm a fine cotton-wool-like growth can be distinguished on the under (sometimes on the upper) surface of the affected areas and especially near the margins. This external growth of the fungus is for the purpose of reproduction and is spore-bearing. The main part of the fungus is found internally, where it ramifies throughout the tissues of the leaves.

The spores are produced in enormous numbers and pass from plant to plant. Wind and other agencies aid in their distribution. Each spore is a potential source of infection to a healthy plant. When once infected the further spread of the disease is controlled largely by the weather

conditions. Wetness and warmth prevailing simultaneously are the conditions most suitable for the development of the fungus. On the other hand, in dry weather the black spots may be limited in area and the affected leaves dry up and shrivel, thus checking the progress of the disease.

A few days of damp, warm weather may be sufficient to transform an apparently healthy crop of growing potatoes into a blackened mass. Soft and slimy, the foliage now emits a peculiarly disagreeable odour which can be felt at a considerable distance from the affected field.

As already noted, weather conditions play a primal part in the development of the disease. Consequently, the date of the external appearance of the fungus varies from year to year and from district to district. The following dates for different areas within the British Isles can therefore only be regarded as approximate:

England: South—middle of June to middle of July.
Midlands—latter part of July.
North—last week in July or first week in August.
Scotland: during August.
Ireland: about the middle of June.

Although September is not mentioned above, it often happens that the disease in dry years is not evident until then.

Blight is a much more serious disease in England and Ireland than in Scotland. This is, in all probability, due to the relatively higher temperatures of the former countries as well as the fact that the disease appears much earlier than in Scotland. The optimum temperature for the development of the disease is stated to be from 72° to 74° F. This obviously will be more closely approached under southern conditions. Again, the moister atmosphere and more abundant rainfall of the west likewise favour the progress of the fungus. Thus the general direction of the development is from south and west to east and north. It is noteworthy that a temperature of 77° F. maintained for a few days actually checks the disease.

It should be remembered that the plants originally affected are the cause of the general attack, and that in these the disease probably begins as soon as the sprouts appear. Such plants are generally stunted in growth and reddish brown in colour.

*Tuber Infection.*—The spores, which we have seen are chiefly produced on the under surface of the leaves, fall to the ground and pass downwards into the soil, thus coming into contact with the tubers and causing infection. There is no evidence to show that the tubers ever become infected by the fungus passing down internally through the tissues into the underground stems.

A blighted tuber at first shows a slight darkening of the skin over the affected area. Later this area becomes slightly sunken and takes on a leaden hue. If a section be cut through the tuber the diseased portion

will be seen to be of a rusty or foxy red colour, which will stand out in sharp contrast to the white flesh of the unaffected portion. The affected area is shallow at first, but the fungus may soon extend rapidly throughout the whole tuber. It is important to note that the decay produced is a typical dry rot. Frequently other organisms invade the diseased areas and give rise to what is termed a wet rot. This, as will be observed, is the result of a secondary infection.

During the storage of the tubers the majority of those affected by blight are destroyed, but, on the other hand, there may be many in which the rot produced is only slight. It is the latter that provide infection to a succeeding crop. There is no other known method of carrying the infection over from one season to another.

Many infected tubers when planted do not produce plants, but rot in the ground. A few, however, do give rise to functional plants, and on the foliage of these there ultimately appear the external reproductive parts of the fungus. As before mentioned spores are formed, and these when shed serve to infect healthy plants. In a growing crop there are thus a few plants which are primarily infected from the seed, but generally the greater number contract the disease through contact with those initially unhealthy.[1]

*Methods of Control.*—The most effective of these is to plant seed which is not infected. All tubers kept for seed should be carefully examined, and those showing any suspicion of unsoundness rejected. It is likewise important to consider the source of the seed, for in this way the trouble may be largely avoided. Thus it is that the English and Irish growers prefer Scotch-grown seed, which is generally freer from blight than seed grown under their own local conditions.

The best method, were it practicable, would be to plant varieties resistant to the disease. Although it is known that varieties show a varying resistance both in the tuber and in the shaw or haulm to the attacks of the blight fungus, yet little has been done so far to determine the relative powers of resistance of even the standard British varieties grown under different conditions of soil and climate. From the incomplete records at present available it is tentatively stated that the following varieties are highly resistant to blight: President and its allies Scottish Farmer and Iron Duke; Shamrock and Champion II; Evergood. Of these Shamrock comes nearest to being immune. The following are very highly susceptible both to tuber and shaw infection: Abundance, British Queen, Arran Comrade, Up-to-date, Champion, King Edward VII. The last-mentioned is especially liable to shaw infection. Some varieties are feebly resistant

[1] Dr. Pethybridge, who has carried out experiments in Ireland extending over a number of years, does not support this view, viz. that blighted tubers used for seed give rise to blighted plants. He is inclined to believe that the disease may be propagated from year to year by some form of resting spore.

and are intermediate to the groups already mentioned. Amongst these we have: Golden Wonder and Langworthy, Arran Chief, Great Scot.

*Control by Spraying.*—Blight can be controlled fairly satisfactorily by the application of sprays. One of the most extensively used is that known as Bordeaux mixture, which owes its name to Professor Millardel of Bordeaux University, who recommended its use in 1885. The prescription for this mixture is as follows:

| | |
|---|---|
| Copper sulphate .. .. .. | 4 lb. |
| Quicklime (freshly burnt) .. .. | 2 lb. |
| Water .. .. .. .. .. | 40 gall. |

This constitutes what is known as a 1-per-cent Bordeaux mixture. Some authorities recommend a 2-per-cent mixture, i.e. one in which double quantities of copper sulphate and quicklime are employed, but it might be emphasized here that there is little, if any, advantage in using the latter, and in view of the high cost, particularly of copper sulphate, the weaker mixture is to be preferred.

The Burgundy mixture, which is likewise a liquid spray, is a modification of the one already detailed. The formula in this case is as follows:

| | |
|---|---|
| Copper sulphate .. .. .. | 4 lb. |
| Washing Soda .. .. .. .. | 5 lb. |
| Water .. .. .. .. .. | 40 gall. |

This mixture (1 per cent) is used by many in preference to Bordeaux mixture of the same strength.

*Preparation of Liquid Sprays.* (*a*) *Bordeaux Mixture.*—A wooden barrel capable of holding 40 gall. is required. The copper sulphate should first of all be dissolved in a small volume of hot water—it is less soluble in cold water—and the solution then made up to 35 gall. by the addition of clean cold water. Generally the sulphate will be dissolved in a smaller vessel, e.g. a wooden pail, before being transferred to the barrel. It is particularly important to note that metal vessels should not be employed for dissolving the sulphate.

The lime should be put into a separate vessel and just sufficient water added to slake it slowly. When completely slaked more water should be added gradually and the mixture thoroughly stirred until the required 5 gall. is obtained. As this lime solution contains a considerable amount of material in suspension, the liquid must be passed through a fine sieve before admixture with the sulphate solution. The addition of the lime to the latter should be made slowly, and care should be taken, by stirring vigorously during the operation, to ensure the rapid and complete mixing of the contents of the barrel. The fineness of the precipitate which is formed depends on the efficiency of the stirring. In a properly prepared

Bordeaux mixture the complex copper salt which precipitates out should remain in suspension for a long time. The finer the precipitate the longer will it remain in suspension and the more effective will be the spray.

Before application the reaction of the mixture should be determined. A piece of red litmus paper dipped into the mixture should become blue; if it remains red then more lime solution should be added until the red colour of the litmus just turns blue.

(*b*) *Burgundy Mixture.*—In the preparation of this the operations are similar. The copper sulphate is dissolved in 35 gall. of water contained in a 40-gall. barrel. The finely pulverized washing soda is dissolved in hot water in a separate vessel and the solution made up to 5 gall. This solution should be filtered if necessary and then slowly added to the contents of the barrel. As before, the mixture during this operation should be vigorously agitated.

When made up the mixture should be light blue in colour and contain in suspension an insoluble copper salt. The better the mixture the longer will this salt remain suspended. Before use it is essential to apply the litmus test, and more washing soda should be added if required. The mixture when complete must be slightly alkaline, and red litmus paper should change to blue on immersion.

Under normal conditions, and provided they are properly prepared, both mixtures should prove effective in controlling the disease, if used in time. There is, however, a certain amount of evidence to show that Bordeaux mixture when sprayed on potatoes near large towns blackens the foliage, and that Burgundy mixture has no such effect. Growers in urban areas, and particularly in industrial centres, would therefore be well advised to use the latter spray. Moreover, pure washing soda is generally more easily secured than good freshly burnt lime, and on this account Burgundy mixture usually adheres more to the foliage than Bordeaux. Whichever mixture is employed, it is important to remember that it must not be allowed to stand more than ten hours before application.

*Method of Application.*—For small areas the use of a knapsack sprayer may well suffice. In general field practice this is too slow and laborious, and the operation requires the use of a horse-drawn spraying machine.

The proper adherence of the spray to the surface of the leaves can only be obtained when the application is made in the form of a fine mist and when the weather conditions are suitable. A dull, dry day is necessary, and preferably early morning or late afternoon should be availed of for carrying out the work. Should rain fall before the spray dries the operation must be repeated.

It is necessary that both the lower and upper surfaces of the leaves be sprayed. This is easily accomplished when using a horse-drawn machine as there are two sets of nozzles, one delivering upwards and the other downwards. A knapsack has only one set, but if the nozzles are directed

Sprayed Unsprayed

BLIGHT

*Facing p. 244, Vol. II*

upwards the spray will fall on both the lower and upper surfaces, or, if this cannot be satisfactorily done owing to large shaw development, the spraying may be carried out twice, firstly by spraying the under side of the leaves from below and secondly by turning the nozzles downwards and spraying from above the shaws.

*Quantity per acre.*—Spraying may be done on two or more occasions. The Irish Department of Agriculture recommend 100 gall. for the first application and 120 gall. for subsequent applications. These quantities may be effectively increased to 120 gall. and 160 gall. respectively.

*Time to Spray.*—Spraying, to be fully advantageous, must be done before the disease shows its appearance externally. As already indicated this will vary with the district and with the season.

The following particulars published by the Ministry of Agriculture give guidance as to the date of the first spraying of second early and main-crop potatoes in England and Wales.

*15th June to 30th June:* Cornwall, Devon, Dorset, Hampshire, Isle of Wight, Somerset, and South-west Wales.

N.B.—Spraying should be done during the last week of May for early varieties in the Penzance district, and in the first week of June in other forward districts in Cornwall, Devon, and the Isle of Wight.

*1st July to 8th July:* Glamorgan, Gloucestershire, Monmouthshire, Sussex, and Wiltshire.

*8th July to 15th July:* Berkshire, Herefordshire, Kent, Oxfordshire, Surrey, and Worcestershire.

*15th July to 31st July:* remainder of the country.

In Scotland, if spraying be done, the first application should be made during the last week of July or first week of August. The first spraying in Western Ireland is generally necessary about the end of June, whilst July meets the requirements of most of the other areas.

It is usually recommended to spray a second time three weeks after the first. If the disease is severe or the season wet a third and even a fourth spraying at intervals of from two to three weeks may be advisable.

In most parts of the country first earlies do not require spraying, and it is questionable if second earlies should be sprayed except in districts where the disease appears early or where the second earlies are not lifted until late in the season.

Spraying gives best results in the south and west of England, including Wales, and in the Fen district. In the north of England the benefits are not nearly so striking, whereas in Scotland the results are frequently disappointing.

*Dry Powder Sprays.*—Within recent years powder sprays have been

put on the market. Some of these give fairly satisfactory results, while others are almost valueless. On the whole they are scarcely as effective as the liquid sprays. The principal advantage of powder sprays is that, on account of their nature, no water is required. A special type of spraying machine is used, and the finely pulverized powder is blown on to the foliage, which must be in a moist condition to allow of the powder adhering to the surface of the leaves.

*Special Precautions.*—It is important that badly blighted shaws be burned. On no account should blighted tubers be left carelessly in the neighbourhood of the pits, and still less should they be consigned to the manure heap.

Earthing up the plants in the drills as late in the growing season as the development of shaws permits will likewise bury the developing tubers and, when blight attacks the plants, prevent the spores finding ready access to the tubers.

There is another form of blight (early blight) common in America, Europe, Asia, and Australia, which is caused by the fungus *Alternaria solani* or *Macrosporium solani.* There is no definite evidence to show that this disease occurs in Great Britain.

### Black Scab, Wart Disease, or Cauliflower Disease.

This disease is first recorded as having occurred in Hungary in 1896. Diagnosed in England in 1902,[1] it spread rapidly there and became so serious that under the Destructive Insect and Pests Order of 1908 it was scheduled as a notifiable disease.

Black scab is most prevalent in the northern and midland counties of England, particularly in the neighbourhood of Manchester and Liverpool, and in Wales. In the other parts of England, although recognized, it has not assumed serious proportions. In Scotland the disease has been noted as occurring mainly in and around the industrial centres of the south-west, while outbreaks in Ireland have so far been confined to a limited area in the north. It is fairly widespread in other parts of Europe, and more recently has been found in Canada and the United States of America.

So quickly has the disease spread from country to country that it has gained world-wide notoriety, and is everywhere recognized as one of the most serious diseases which the potato grower has to combat. This is in part due to the great loss which an outbreak may cause in a single season, but more especially to the fact that, unlike most potato diseases, the spores of the organism causing the trouble persist in the soil and no practicable method has yet been devised which will rid such a soil of infection.

The disease is most prone to occur among potatoes grown in gardens and allotments, probably because the owners of such take less care in the

[1] There is reason to believe that the disease existed in England prior to this date.

BLACK SCAB

*Facing p. 246, Vol II*

selection of their seed and grow potatoes more frequently on the same land. In areas where the disease is rampant it is found attacking tubers grown under field conditions.

*Appearance in the Field.*—The shaws or haulms of affected plants as a rule give little indication of the presence of black scab. Consequently the disease may be quite easily overlooked until the crop is harvested. The fungus attacks mainly the underground parts of the plant. In the early stages small whitish wart-like outgrowths are formed at the eyes of the tuber. These warts rapidly increase in size and several may coalesce to form larger irregular outgrowths which are often bigger than the tuber on which they are located. Warts occurring near the ground surface may be green in colour. As the season advances the outgrowths become black and are finally transformed into a dirty, wet mass giving off a most unpleasant putrefactive odour.

In some varieties the tubers are very badly affected, while in others the extent of the disease never reaches marked proportions. A few small warts may simply be found round the eyes, giving the cauliflower appearance: hence the name often applied. It would also appear that the tubers of a diseased plant are not all equally susceptible to the disease. Those near the ground surface may be badly affected, whereas small, late-formed tubers, especially if they are deep in the soil, may be either free from warts or show them only in diminutive form.

The wart-like outgrowths are not always confined to the tuber but are found on the collar of the haulm, either just above or below the ground surface, or on the ends of underground runners, especially if these rise to the surface. Rarely do we find the occurrence of the disease on the aerial stems. In one case, however, a wart was observed on the mature stem close to the flower. Sometimes the leaves nearest the ground may be affected, and become distorted in appearance. The roots on the other hand are free from warts.

Although the foliage of an affected plant may not always reveal the presence of black scab, yet plants so affected are generally larger and greener and continue to grow later in the season. Further, it should be noted that the severity of an attack of black scab is dependent on the nature of the season. For instance, in dry seasons, and especially on a light soil, the wart-like outgrowths may be very rudimentary.

*Cause of the Disease.*—The disease is caused by the fungus *Synchytrium endobioticum* (Schilb.), Percl., which is known in American literature as *Chrysophlyctis endobiotica*. To a small extent the fungus also attacks the Woody Nightshade (*Solanum dulcamara*) and the Black Nightshade (*S. nigrum*).

*Life History of the Fungus.*—This fungus, like its group members, produces no definite mycelium. If a diseased tuber be cut through, the fungus in the form of a sporangium can be detected lying close to the

surface. Here it sets up an irritation within the cells which results in these rapidly dividing and giving rise to the formation of the wart. A fresh wart under a lens will reveal relatively large spores as brown specks. These occur most profusely just beneath the skin.

The fungus, it is believed, produces two kinds of sporangia: (*a*) summer, and (*b*) winter. The former are produced during summer, and on rupture set free a large number of very active zoospores, or swarm spores, which serve to invade fresh healthy potato tissue. In the late-growing season winter sporangia are formed which produce resting spores intended for carrying infection over to the succeeding season. A sporangium of the latter type is surrounded by a hard tough case, and on the decay of an affected tuber it passes into the soil, there germinating under favourable conditions. It has not been definitely established how long a resting sporangium can remain dormant in the soil, but it has been shown that under certain conditions it can at least persist for eight years.

A resting sporangium on germination gives rise to a large number of motile zoospores, each of which is capable of infecting a potato tuber. Thus the disease may be transmitted from unhealthy plants grown many years previously.

*Spread of the Disease.*—Infection may be carried to clean land by spores adhering to the boots of persons walking over infected soil, or, in like manner, by the agency of the implements of cultivation. The bird may also be considered as a probable carrier of the disease from field to field. Farmyard manure contaminated with the disease spores may also contribute to the spread of black scab. Peelings or affected tubers or shaws thrown into the dungstead will undoubtedly lead to contamination, as also will diseased tubers fed to stock. It is known that the spores pass through the alimentary tract unharmed.

There is reason to believe from our experience that the disease is propagated by planting diseased tubers which only show slight signs of infection. A slight wart on the tuber may escape detection, or, further, it may be broken off and leave a small, apparently innocent scar.

The natural spread of the spores in the soil through the movement of soil water is relatively insignificant. On level land it is estimated that spores travel at the rate of 9 in. per annum; on sloping land the rate of progress varies up to 28 in. per annum; and always, as expected, in the direction of the slope, and not uphill.

The wind, as far as is known, plays little or no part in the transmission of the disease. The spores, occurring as they do in the interior of the tuber or in the soil, do not lend themselves to transport in this way.

There would seem reason to suppose that infected soil adhering to the surface of tubers, both immune and non-immune, may be a means of transmission.

*Control of the Disease.*—It is extremely fortunate for the potato grower that certain varieties have been found to be immune to this disease, and that this characteristic is of a permanent nature. There is no record of any variety which has been definitely classed as immune ever becoming non-immune. Occasionally a variety, as for instance Kerr's Pink, has been suspected of being an exception to this rule, but careful investigation has shown that in all cases the trouble has been due to the presence of non-immune impurities or rogues. Some rogues, especially those in stocks of Kerr's Pink, are extremely difficult to detect, and these on occasions have given rise to much concern among potato experts.

So far it has not been possible to connote immunity with any demonstrable character of the plant or tuber.

The provisions of the Wart Disease Order of Potatoes, 1918, are summarized as follows:

1. All occupiers of land on which the disease occurs must at once report an outbreak to the Board, to an Inspector of the Board, or to the Local Authority of the district.

2. Occupiers in reporting outbreaks must give full name and their postal addresses.

3. It is illegal to sell or offer for sale for any purpose potatoes that are visibly affected with wart disease.

4. Apart from exceptional cases, only approved immune varieties of potatoes may be planted in an area which has been scheduled as an "infected area" or on land to which the provisions of the order relating to infected areas apply.

5. It is an offence under the order to sell, or purchase, or use potatoes grown in any area or land mentioned in the last clause for planting in land not in an "affected area" or not affected by the order.

6. Approved immune varieties of potatoes may not be sold for planting except to a dealer in seed potatoes unless the seller has a licence granted by the Board, and growers should, before purchasing seed potatoes of such varieties, ascertain whether the vendor has received the requisite licence.

Any contravention of orders dealing with the disease renders the person offending liable on conviction to a penalty not exceeding £10.

## Black-leg, Black Stalk Rot, Basal Stem Rot, or Tuber Rot.

This disease becomes evident in the field earlier than any other affecting the potato crop. It is particularly widespread, and almost every field inspected will reveal at least single plants attacked by it.

*Cause.*—The disease is bacterial, and is caused by the organism

*Bacillus melanogenes*.[1] The damage is done mainly to the tuber in which a destructive wet rot is set up.

*Symptoms*.—Diseased plants, at first, are pale green or yellowish in colour and of stunted appearance. Later they become limp and drooping. Sometimes only a single stem is affected, but more often, and especially when the disease has progressed, all the stalks of the affected plants are attacked. A diseased stalk can be easily pulled out of the ground. An examination of the base of the stalk, from the underground portion to 1 or 2 in. above the ground-level, will show a distinctly blackish colour accompanied by the softened condition which permits of the easy detachment of the stem. The roots will be found to be similarly affected. Any tubers formed by affected plants are small.

If a diseased stalk be cut across a few inches above the ground-level three well-defined dark-coloured areas will be seen in the corners corresponding to the vascular systems of the stem. In a plant affected for some time these blackened areas can be traced right up the stems, even to the uppermost leaves. Decay sets in at this stage and the stalks become black and rotten.

In the tuber, during the early development of the disease, a black ring is found at the point of attachment to the stem. It is evident from this that infection is traceable to the parent plant, and is transmitted directly through the underground stems to the tubers. Early infection leads to the rapid blackening and rotting of many of the tubers in the soil, the result being a typical wet rot. Cavities occur in the interior of tubers which have rotted on account of this disease. Others again may be only slightly infected even at lifting time, in which case rotting may or may not advance according to the conditions under which the tubers are stored or pitted. Such tubers, though apparently healthy, will transmit the disease to the following crop if used for seed purposes. Further, a few diseased tubers in a pit may serve to infect healthy tubers and considerable damage results.

*Control*.—Although the soil becomes contaminated by the decay of the various portions of diseased plants, it seems certain that the seed and not the soil is the source of infection. The earliness of the attack likewise points to seed transmission of the disease.

Control measures are limited to the burning of all diseased plants as soon as these are noticeable, and to the thorough ventilation of the pits in which the tubers are stored. As with many other potato diseases, suspicious tubers should not be used for seed purposes.

[1] In America, Smith distinguishes a black rot of the potato caused by *B. phytophthorus*, Appel, from a brown rot caused by *B. solanaceæ*, E.F.S. He states that *B. melanogenes* supplied him is a mixed culture. Recently it has been shown that the disease in this country is analogous to that caused by *B. phytophthorus*, and the causal organism is now given that name by most authorities. Some prefer Harrison's name, *B. solanisaprius*, or van Hall's name, *B. atrosepticus*.

Black Scab

Corky Scab

Brown Scab

SCAB DISEASES OF THE POTATO

*Facing p. 250, Vol. II*

## Pink Rot.

This disease is caused by another species of Phytophthora, namely *Phytophthora erythroseptica* (Pethybridge). It is fairly common in Ireland, particularly in the west, and has now been diagnosed as occurring in England and Scotland. Probably in the past it was not distinguished from the tuber rots brought about by ordinary blight, black stalk rot, or dry rot.

*Tuber Symptoms.*—The disease is most easily recognized by the colour changes which occur when an affected tuber is cut and exposed to the air. At first the diseased portion of the flesh may be more or less similar to the healthy portion, or, if distinguishable, the former, especially near the skin, may be somewhat dull and dirty in appearance. Soon after cutting, the diseased portion develops a pink colour which will be well marked at the end of half an hour. Following this the colour generally deepens, first to a purplish brown and then to a brownish black.

The tubers—usually the larger and older ones—are attacked while still in the ground. The disease appears almost invariably at the heel end, and from there the rotting progresses fairly rapidly towards the rose end until the whole tuber is completely affected. This indicates that infection comes from the underground stems.

As frequently happens when a potato tuber is killed by the invasion of a fungus, it becomes an ideal medium for the development of micro-organisms which cause it to rot away completely in the soil. Such secondary rotting must be distinguished from the changes in the tuber brought about by the primary infection.

A tuber invaded only by *Phytophthora erythroseptica* is more or less soft and rubber-like, but not pulpy, and without any cavities in the flesh. (Tubers affected with black stem rot differ in these respects.) The skin over the affected area is discoloured and, being loosely attached, can be readily peeled off. If the tuber has on its surface any depressions or wounds, these, as well as the lenticels in the affected part, are usually black in colour. Affected tubers have a somewhat pungent odour.

*Foliage Symptoms.*—In addition to attacking the tuber, the fungus invades the stem and all the tissues of the plant below ground. The foliage changes are therefore somewhat similar to those caused by black stalk rot, i.e. they are of the wilt type. From about the middle of August onwards the foliage of affected plants turns pale green or even yellow, while the margins of many of the leaflets of the younger leaves roll upwards and inwards and become brown, dry, and crisp. Areas of dry, brown, dead tissue occur scattered over many of the leaflets.

Aerial tubers are frequently found on the stem close to the ground, and the underground stems may be rotten, blackened, and shrivelled.

Resting spores (oospores) are found in the underground stems and in rotten tubers. These serve to contaminate the soil and render it prone

to repeat the disease unless the interval prior to the succeeding potato crop is sufficiently long, after which probably most of the oospores will have perished.

It has been already noticed that the tubers receive their infection directly from the underground stems. It would appear that the latter, as well as the roots, are previously attacked by the germinating oospores which send their fine germ tubes into the tissues of those parts of the plant.

The disease is most prevalent on land where potatoes are closely cropped without any proper rotation. Under such conditions the losses may be very serious, even more so than from blight. Fortunately, the disease does not spread from diseased to healthy tubers in the pit. (Black stem rot differs also in this respect.)

*Control.*—Seed from healthy land should always be used, as tubers grown on infected land may transmit the disease by spores adhering to their surfaces. Such tubers are not actually diseased, for there is little danger of a diseased tuber surviving the winter owing to rapid rotting; but, nevertheless, they are carriers of the disease.

Varieties differ in their power of withstanding the disease. Those showing the most opposition, as at present ascertained, are, arranged in order of resistance: Kerr's Pink, Dominion, Burnhouse Beauty, Provost, and Great Scot.

### Leaf Curl, Leaf Roll, or Phloem Necrosis.

This disease, like mosaic or curly dwarf, to which it is closely related, has received much attention in this country during the past decade. Nevertheless, it has been known to occur in Great Britain since 1770, or almost as early as the introduction of the potato crop. Its true significance, however, was not realized until 1905.

Previous to this the curl in the leaf was variously ascribed to climatic or soil conditions, and the potato was said to be degenerating or running out. In 1905, in western Germany and adjacent countries, the disease caused special attention to be focused upon it by markedly affecting the yield and vigour of the crop. In two years time, as a result of continued observation, it was found that the trouble was even more serious than was at first thought. It was located in northern, central, and south-eastern Europe, and a few years later—in 1911 and 1912—caused serious losses to the potato growers in the United States. It is now recognized that the disease is as world-wide in its distribution as the potato itself, and is possibly one of the most important diseases affecting this crop. In spite of the great amount of research which has been carried out upon this disease, nothing definite has been put forward as to the real cause. Many believe the trouble to be due to an ultramicroscopic organism, others say the cause is enzymic (see "Mosaic", p. 256).

LEAF ROLL

*Facing p.* 252, *Vol. II*

*Symptoms.*—The first external symptom is noticeable about two months after the sets are planted. The leaflets of the lower leaves become thickened and leathery and begin to roll upwards at the edges, the roll commencing at the base of the leaf. The rolling may be confined to the lower leaves throughout the entire season, or spread to the upper leaves to such an extent that practically all the leaves are involved.

As the season advances the affected leaves take on a pale colour, dark spots develop upon them, and they dry up at the tips. They are harsh to the touch and rattle if brushed with the hand. The lower exposed surfaces appear silvery or purplish in colour. Affected plants seem to be unduly upright and present a stunted and unhealthy appearance, the last-mentioned symptom arising from the yellowish green or reddish coloration of the foliage. As a rule, however, such plants do not ripen prematurely.

Rolling of the leaflets is a symptom of many other diseases, and it must be emphasized that in the past much confusion arose through regarding all cases where rolling occurred as indicating this disease. In reality it is often due to other causes. It is a symptom of black-leg, of verticillium disease, of rhizoctonia, and even of black scab. True leaf curl is, however, distinguished from these by the hard and leathery nature of the affected foliage.

The shaws or haulms, as well as the root, rhizomes, and tubers, are apparently unaffected. The yield is, however, as a rule considerably reduced, and small and medium-sized tubers form an undue proportion of the crop. Certain varieties are outstanding in that they produce satisfactory crops even when badly affected. The tubers are often found close to the main stem, at the base of which the old set is usually in a sound condition when the crop is dug.

It is customary to distinguish two forms of leaf roll. The first, as already described, is known as secondary leaf roll and is traceable to the diseased tuber; the second, called primary leaf curl, arises when a healthy plant becomes infected during the growing season, not from the tuber but from any other affected plant. The disease, in the latter case, may not make itself evident during the season of infection, although sometimes the rolling commences at the top leaves and spreads downwards. The yield may not be reduced to any extent by this form. During the following season, however, it appears as secondary leaf roll.

The phloem in the stems of diseased plants is more or less disorganized and broken up. Phloem necrosis is a constant symptom of the disease. Net necrosis is often but not invariably seen in the tubers, but all tubers so affected give rise to diseased plants.

Recently it has been shown that starch accumulates to a relatively large extent in the rolled leaves. Apparently the starch cannot be translocated from the leaf to the tuber, since the phloem is destroyed.

This will cause the stunted appearance and retard tuber formation.

The disease is transmitted from an infected plant to a healthy plant through the agency of insects which feed upon the potato plant. Aphides (green fly) seem to spread infection to the greatest extent abroad, but in this country the capsid bugs and the jassids are more commonly found on the potato, and appear to be responsible for the transmission of the disease.

The disease can be spread, when the potato tubers are boxed, by insects carrying infection. In this respect it has been noticed that a crop when boxed is more liable to "roll" than when the sets are unboxed. The first intention (shoot) of a boxed tuber is the one in which infection is present in largest degree. Fumigating boxed sets with tetra-chlor-ethane has been found to be effective in killing aphides, and this should be done when these are found to be present in the boxes.

*Susceptibility.*—It is known that some varieties are peculiarly susceptible to leaf roll while others seem to be more or less resistant. Others again appear to have considerable powers of resistance, but when once infected they contract the disease very badly. According to the Irish Department of Agriculture, the following table shows the order of resistance of the leading varieties.

*Varieties comparatively resistant*—not more than 40 per cent of plants infected.

| | |
|---|---|
| Champion II. | Silver Shamrock. |
| Lifden Seedling | Striped Shamrock. |

*Varieties rather susceptible*—40 to 75 per cent of plants infected.

| | |
|---|---|
| Ally. | Majestic. |
| Arran Comrade. | Resistant Snowdrop. |
| Dominion. | Sharpe's Express. |
| Epicure. | Sutton's Flourball. |
| Irish Chieftain. | Tinwald Perfection. |

*Varieties very susceptible*—more than 75 per cent of plants infected.

| | | |
|---|---|---|
| Abundance. | Great Scot. | President. |
| Arran Chief. | Irish Queen. | Provost. |
| British Queen. | Kerr's Pink. | Summit. |
| Duke of York. | King Edward. | Templar. |
| Eclipse. | May Queen. | Up-to-date. |
| Edzell Blue. | Midlothian Early. | Witchhill. |

It will be seen that the variety Great Scot is grouped with those that are very susceptible. This is contrary to the general opinion in Scotland and England, where it is believed to be remarkably free from leaf roll. It should be borne in mind, however, that the freedom of any variety

from apparent infection does not necessarily mean that such variety is more or less resistant to the disease. In the case of comparatively new varieties it may be that the plants have never been subjected to severe infection.

It must be emphasized that it is possible in most varieties, even those listed as most susceptible, to secure seed that is free from the trouble. Taking the crop as a whole, however, investigations indicate that the farther north one goes in the British Isles the less leaf roll is met with. This points to temperature having a controlling influence on the prevalence of the disease. In the south of England a healthy variety seems to contract the disease in a short time. Farther north infection is slower, whilst in Scotland, and especially in the north of Scotland, a healthy variety tends to remain uninfected. This fact accounts to some extent for the popularity of Scotch seed potatoes in England and Ireland.

It has been ascertained that the optimum temperature for the development of the disease approximates to that of mosaic (57° to 64° F.). That being so, it is obvious that this temperature is more closely approached the farther south the crop is grown. On the other hand it is held by some that the influence of temperature is indirect, in so far that the insects which carry infection are less able to persist under the colder conditions of the north, and vice versa. Possibly the true explanation involves both points of view, namely that the optimum temperature, as approached in the south, facilitates the development of the insects as well as the disease; also, that any condition which restricts insect development will, at the same time, restrict the spread of the disease.

*Control Measures.*—It has been suggested by some authorities that the best control measure would be for each grower to select his seed from roll-free plants. Provided the affected plants were removed from the growing crop very early in the season, this might prove an efficient way of combating the disease. If this precaution, however, were neglected until the season was too far advanced, or if the temperature were favourable for the development of the disease-carrying insects and for the transmission of the disease, then many of the apparently healthy plants would have contracted primary leaf curl, although no symptoms of such might be evident in the foliage.[1]

This method of control is of use in Scotland, but in England and Ireland it is rather disappointing. A change of seed at frequent intervals from healthy stock is the measure adopted by English and Irish growers, and the only one that meets the difficulties. It seems possible to suggest that best results would be obtained by the use of seed from the far north.

No practicable methods have yet been devised which will prevent the

[1] Where a variety shows a tendency to produce sports, it seems feasible to expect that some of these sports might be resistant to the disease, and selection in such a case would be effective.

development of the insect carriers. Spraying, unfortunately, has no injurious effect on them. The cleaning of such shelters and breeding grounds as hedge bottoms, ditches, and headrigs should, however, be attended to. Neglect in this respect will lead to an increase in numbers and, consequently, the spread of the disease will be facilitated.

In the near future more attention may be paid to breeding new varieties which are highly resistant to the disease. Unfortunately the potato is subject to so many distinct diseases that it is almost too much to hope that a variety will be obtained which will be resistant to even the more important of these. The problem demands further investigation, and research may yet show a definite relationship between certain determinable characters in the different varieties and immunity or resistance to the various diseases of importance which attack the crop as a whole. Should such characters be determined and judiciously transmitted in the evolution of a new variety, it is not improbable that a type will be obtained which will, at least, be resistant to the commoner potato diseases. Until then we must rely on seed selection and the maintenance of healthy stocks by removing infected plants from the growing crop as soon as the disease becomes apparent.

Growers of seed potatoes and those raising new varieties should bring forward their seed stock on ground as far removed from other growing potatoes as is possible.

### Mosaic or Curly Dwarf.

The old disease known as leaf curl, formerly diagnosed as the common cause of the " degeneration of a variety ", included at least two distinct diseases, viz. leaf roll and mosaic.

Mosaic is in many ways closely related to leaf curl and, like the latter, has been known to attack the potato crop in Great Britain for more than two centuries. The symptoms of the two diseases are, however, more or less distinct, and at the present day no difficulty is experienced in differentiating between them.

In addition to attacking the potato crop, mosaic affects all members of the natural order Solanaceæ, particularly tobacco, and is intercommunicable to a certain extent between them.

*Symptoms.*—The disease is comparatively easy to diagnose. The leaves of affected potato plants are mottled, with light green or yellowish green spots which vary greatly in abundance, location, and shape. These spots may be few in number and confined to a part of the leaf or they may be numerous and scattered over the whole leaf. They are seldom more than ¼ in. in breadth, and the shape, though often irregular, may be circular or elongated.

The foliage, especially in severe cases, is generally wrinkled or distorted; this is the first noticeable symptom of the disease. The accompanying

Plant Attacked Healthy Plant

MOSAIC DISEASE

*Facing p. 256, Vol. II*

mottled appearance is most obvious in dull, showery weather, although at times mottling may not be apparent. The leaves and the constituent leaflets are small and the foliage crowded together, while the leaf veins are unduly prominent.

Badly affected plants are generally stunted and dwarf in habit; hence the alternative name curly dwarf. Curly dwarf and mosaic are therefore one and the same. Until recently, however, the former was considered to be a specific disease.

Symptoms of the disease may not be evident during the first year of infection, but in succeeding years the trouble becomes increasingly worse until the curly dwarf stage is reached. The tuber yield is then almost negligible.

The loss in yield varies with the variety, with the season, and with the intensity of the disease. Some varieties will only yield half a crop when affected, while others badly affected may show only a slight diminution of yield. Generally speaking an affected plant will not, on an average, produce more than three-quarters of the yield that might, under healthy conditions, be expected of it.

Investigations seem to point to an accumulation of sugar in the leaves of affected plants and a reduction of the starch content. The reduced tuber yield is in all probability the direct outcome of this.

Mosaic plants do not ripen prematurely, in fact the reverse obtains. The tubers remain sound and are apparently healthy. They thus present, as far as present knowledge goes, no means of detecting the presence of the disease at this stage.

*Cause.*—No causal organism has yet been isolated. Two theories are, however, advanced as possible explanations of the trouble: (*a*) that the disease is due to an ultramicroscopic organism, and (*b*) that the cause is enzymic. One cannot, at present, state definitely which theory is correct, but the second, which points to the disease resulting from a disturbance of the balance of the enzymes in the plant, finds few supporters.

The disease is spread in the same way, and by the same species of insects, as in leaf roll. Thus, primary and secondary infection may occur in the same field, the latter on plants grown from infected seed and showing marked symptoms of the disease. Primary infection, or infection of the healthy plants from those already affected through the tuber, can often only with difficulty be recognized. Usually three or four generations are required before a plant reaches the acute, or curly dwarf, stage of the disease.

*Methods of Control.*—Control measures are similar to those advocated for leaf roll. There is likewise a varietal resistance to the disease, but again one must emphasize the point that a variety which is apparently highly resistant may only be free from disease because it has never been exposed to infection. Hence in the case of a new variety it is evident that no

hasty judgment should be come to as regards its susceptibility to mosaic. On the other hand most of the old varieties, and particularly Langworthy and Golden Wonder, are badly infected. In fact, it is almost impossible to obtain a plant of the varieties just named which can, without any doubt, be said to be free from mosaic.

It is more difficult to get rid of mosaic from a stock by selection than it is to secure a stock free from leaf curl. In consequence of this any selective measures so far practised have met with little success.

The optimum temperature for the development of mosaic lies between 57° and 64° F. As with leaf roll, it would appear that variations from this temperature limit the spread of the disease. At any rate seed stocks from the northern parts of the British Isles are generally freer from mosaic than those raised in the south.

In the case of mosaic it is important to remember that the disease may probably persist from year to year in solanaceous weeds. Fortunately these weeds are not found growing in Scotland to any extent, but in some parts of England they are fairly common on arable land, and their eradication as a means of checking mosaic should not be overlooked.

The growing of potatoes from seed-size tubers will undoubtedly spread the disease if the stock is infected. Practically the whole of the produce from a badly diseased plant will find its way into that category. It would therefore be reasonable to expect that if a farmer intends to grow an old variety susceptible to mosaic, he would secure best results by selecting large sets and, if necessary, cutting them before planting.

At the present day there seems to be no question that, if growers of seed potatoes were adequately repaid for the labour which they might spend in eradicating leaf roll and mosaic from their stocks, the more enlightened would contrive to do so. If it were made compulsory for growers of seed potatoes to secure certificates from competent authorities showing the extent of mosaic and leaf curl in their crops, then farmers as a whole would soon recognize that the productivity of a variety depends largely upon its freedom from these diseases. Consequently the enhanced price required for the production of healthy seed would be the more willingly paid.

### Silver Scurf or Dry Scab.

This disease, although commonly found on tubers, is relatively unimportant. It has been known to occur in Europe since 1871.

*Cause.*—The disease is caused by the fungus *Spondylocladium atrovirens*, Hartz, and appears to be specially prevalent on potatoes grown on light soils.

*Symptoms.*—In the early stages depressed and slightly discoloured areas can be recognized on the tuber. In these areas the resting or sclerotial stage of the fungus may be seen in the form of small, black specks.

These sclerotia under suitable conditions germinate and produce spores.

When affected tubers have been lifted for some time, and especially when they are allowed to " green ", the areas above mentioned become whitish or silvery in appearance. In severe cases the skin may fracture over the affected part and flake off.

There is no evidence to show that the fungus causes any rotting of, or damage to, the tubers on which it is present. In view of this it would seem that too much has been made of silver scurf, particularly in America, where it was first described in 1908.

## Corky Scab or Powdery Scab.

This disease has been known in Europe since 1841. At the present time it is to be found in all European countries, in Canada, and in the United States. In the case of the last mentioned it was first reported in 1913. Quite recently, also, it has been discovered affecting wild potatoes in Peru, and it is probable that South America furnishes us with the home of the disease. (See Plate facing p. 250.)

*Cause.*—The fungus causing the disease is known as *Spongospora subterranea*, Johns. The name has been frequently changed, and the organism has been classified under various groups of fungi during the last eighty years.

*Prevalence.*—In Great Britain the disease exists to the greatest extent in the moister parts of the country. Consequently we find it more prevalent in Scotland and Wales than in England. In Ireland it is mainly confined to the wet, badly drained, peaty soils on the west coast.

*Symptoms.*—As the name indicates, the disease is one which affects the tuber. In the early stages the fungus localizes itself at a point, and the attack takes the form of small isolated pimples or warts on the potato skin. These arise as the result of the invaded cells being irritated and excited to growth, and are at first covered over with the unbroken skin of the tuber. If the tubers are washed at this stage the affected parts are white; soon afterwards they appear brownish in colour.

The development of the brown colour is due to the fungus in the interior of the swelling producing a considerable amount of fine powder made up of brown " spore balls ". Each spore ball consists of a number of spores bound together into a minute sponge-like mass. Owing to the growth of the fungus in the interior of the swelling, and the development of spore balls, a stage is soon reached when the overlying skin ruptures and the spore balls are exposed. Many of them escape before the potatoes are harvested, thus serving to contaminate the soil, but a considerable number remain in a depression or scab found at the affected spot.

The formation of the depression is caused by the decay of the cells affected, followed by the release of the spore balls. It is often very difficult to distinguish, with the naked eye, the scab caused by this

fungus from that caused by the fungus which produces ordinary brown scab.

If the injury to the tuber consisted simply of a varying number of small scabs on the exterior the damage would be negligible, as the flesh below the scab is quite sound. Unfortunately under certain conditions the damage may be much more serious, the disease sometimes taking the form of a canker in which the tissues of the tuber are to a considerable extent affected and ultimately destroyed. In this case the injury to the flesh is extensive and a large deep wound is left.

Frequently one finds that the tubers badly affected are very irregular in shape and present one or more abnormal swellings or outgrowths from the surface. It has not yet been determined whether such abnormalities are produced by the organism or result as an effort on the part of the plant to free itself from the fungus. Generally a deep wound is present on the surface of the outgrowth. As would be expected, the extent of the injury varies widely between the more or less mild surface scab and the deep canker form.

In addition to attacking the tubers the fibrous roots may be affected. Small root galls or tubercles, which discharge spore balls, are often found on the roots. These generally appear early in the growing season, and may consequently be overlooked. They do not apparently do much injury to the plant.

The loss or damage caused by corky scab is variable. In the mild form the tubers are not injured to any appreciable extent, and, although unsightly and of less value on this account, they are generally wholesome. On the other hand, if the crop has been attacked by the severe form the produce may be so badly affected as to be almost unsaleable.

*Predisposing Causes of the Disease.*

1. Wetness.—The disease is apt to be prevalent on a wet, badly drained soil or during a wet season.

2. The reaction of the soil.—The trouble is most evident on soils to which lime or ashes have been recently added.

*Special Distinguishing Characters of Corky Scab.*—Mild forms of corky scab may resemble ordinary brown scab, but in the case of the former the scabs are more regular and uniform in shape, and usually part of the broken skin persists round the scab margins. The spore balls can also be generally located in the cavities in the form of a brown powder, whereas no such powder can be distinguished in ordinary scab. Again, in corky scab, a relatively deep, brownish, corky layer lines the cavities; in ordinary scab this layer is comparatively thin. A microscopic examination will at once differentiate the two diseases in that it will always reveal the spore balls of corky scab. Bad cases of the latter may also be confused with black scab, although here, as before, there are microscopic differences.

*Transmission of the Disease.*—The main methods by which infection is carried and transmitted are as follows:

1. On the rupture of the swelling, spore balls are discharged into the soil, where they may serve to infect crops in subsequent years. Probably they remain dormant during winter and germinate as soon as warm weather sets in. Each component spore of a spore ball gives rise to a very large number of minute, actively moving swarm spores or zoospores, which move about in the soil until a young potato tuber is encountered. On gaining entrance the disease is set up afresh.

2. Some spore balls are generally found in the scabs on the surface of the tubers. Such tubers, used for planting purposes, serve to transmit the disease. Further, a scab-free set, by reason of contaminated earth adhering to its surface, may also act as a carrier of infection.

3. Scabby tubers or parings, or spore balls in the sweepings from potato sheds, when deposited in farmyard manure add to the probability of the disease.

4. Human and mechanical agencies also play a part in broadening the area of infection.

*Control Measures.*

1. Scabby potatoes must not be used for seed purposes.

2. Slightly affected tubers or suspected seed should be steeped for three hours in a solution made up of ½ pt. of formalin in 15 gall. of water.

3. On badly infected land the potato crop should receive as far as possible those artificial manures which are acid in reaction, in order that the acidity of the soil may be increased. The use of flowers of sulphur at the rate of 6½ cwt. per acre or 2½ oz. per square yard may be advocated in this connection. On the other hand, lime and ashes should be avoided, as these aggravate the trouble.

4. As the disease occurs to greatest extent on wet, poorly drained soils the efficient drainage of the soil will undoubtedly improve matters.

5. Bags contaminated by spore balls as the result of containing previously scabby seed should never be used for holding clean seed.

6. Badly infected tubers as well as potato parings should never be deposited in the dungstead, but, instead, should be boiled and fed to pigs.

7. As the spore balls in some form or other retain their power of infection for at least five years, rotations longer than this period should be aimed at.

8. The use of soil disinfectants is impracticable and at all events ineffective.

9. So far as is known there is no varietal variation in resistance to this disease.

**Common or Brown Scab.**

This form of scab probably exists in all countries where the potato is grown, and particularly is it prevalent in Europe, Africa, New Zealand, and the United States. It is to the last named that we owe most of our present knowledge of the disease. Elsewhere it has been little studied, despite its almost universal prevalence; this may be accounted for by the fact that the damage done is less serious than that caused by many of the other potato diseases. (See Plate facing p. 250.)

*Cause.*—Brown scab was originally described as being caused by the fungus *Oospora scabies*, Thaxter. Recent work, however, has shown that the causative organism is one of the higher bacteria whose technical name is given as *Actinomyces scabies*, Gussow.

Besides attacking the potato, the disease affects the roots of a considerable number of other plants, the most susceptible of which are beets, cabbages, turnips, and carrots.

The trouble is exceedingly common in gardens and allotments, especially where potatoes have been grown in close succession or where alkaline manures like lime and ashes have been freely applied.

*Method of Attack.*—The organism may invade the tubers at any stage of growth. If infection takes place when the plant is quite young the scabs are deep, whereas an attack later in the season, when the tubers are well formed, generally results in shallower injuries. In severe cases, however, the tuber is furrowed or cracked. These symptoms are frequently exaggerated by the incursion of minute insects which cause a deepening of the depressions.

The scabs at first appear as very small, reddish, or brownish spots on the surface of the tuber. If the latter is in the first stage of development the spots will often coincide with the position of the lenticels. Later they gradually extend in surface area and depth, and assume a darker brown hue.

The scab itself consists of a comparatively thin corky layer formed as a result of the irritation set up at the point of attack. In reality it represents an attempt on the part of the tuber to rid itself of the invading organism. Towards the end of the growing season much of this corky material falls away and a more or less deep wound is left.

Scabs of this nature may be few in number and not affect the value of the tubers appreciably. If they are so numerous as to cover the surface almost completely and produce a badly scabbed sample, the selling price is adversely affected, whether the tubers are intended for consumption or for seed purposes. Fortunately, tubers after lifting are not subsequently invaded by the organism, and hence on storing no further damage is done.

*Predisposing Causes.*

1. The reaction of the soil.—Alkalinity, as induced by applications

of lime, ashes, and farmyard manure, facilitates the spread and development of the disease. It has been shown that soils with a hydrogen ion concentration of $P_H$ 6 to 7 are particularly prone to scab.

2. Wetness.—Although scab develops very readily on unduly dry soils, this is likewise a predisposing factor.

3. A soil rich in humus, as supplied by farmyard manure, seems to favour the spread of the organism. On the other hand, ploughing in green crops retards its development.

The organism is believed to be present in practically all soils, and probably plays an important part in soil fertility. In all likelihood it assists in the process of putrefaction. Some workers hold that the organism is always in search of cellulose, and that this may account for the marked prevalence of scab on soils liberally supplied with dung.

*Control Measures.*—It is evident, owing to the wide distribution of the organism in many soils, that little can be done to prevent the spread of the disease. Control measures will, therefore, mainly aim at producing soil conditions unfavourable for the development of the organism. These consist in the withholding of lime, ashes, and farmyard manure, and in the application of acid artificial manures like superphosphate and sulphate of ammonia to the crop. In gardens and allotments flowers of sulphur may be applied at the rate of 1 oz. per square yard.

The use of scab-free seed, though to be recommended, is only partially effective in controlling the disease. If the soil conditions are favourable for the growth of the organism a completely healthy crop need not be expected. The amount of scab in the crop will, however, be lessened. On the other hand, on soils unaffected by brown scab, scab-free seed are a guarantee of further freedom from the disease. The efficacy of this method of control, viz. clean seed, is determined by the soil conditions.

American results would indicate a varietal variation in resistance to scab, but so far nothing is known on this point in this country.

Disinfecting the seed prior to planting, as is recommended under corky scab, may be practised under certain conditions. Immersion for two hours in the formalin solution is necessary in order to obtain best results. It should be noted, in addition, that badly scabbed tubers, even when disinfected, fail to germinate, and accordingly should never be used for seed.

A further precautionary measure is to prevent contamination of the farmyard manure by withholding from the dungstead scabby potatoes and peelings from affected tubers.

A rotation in which susceptible crops are eliminated will help to check the disease. Further, during the rotation green manuring should be practised.

### Dry Rot of the Tuber.

This is a fairly common disease and makes itself evident chiefly during the winter and spring months in tubers which were sound at the time of lifting. As a rule the early varieties of potatoes are most subject to it, although later types may on occasion be affected.

*Cause.*—Dry rot was at first ascribed to a fungus belonging to the genus Fusarium. While this was partly correct, it has been recently shown from work done in Europe and America that a considerable number of species of Fusarium can cause rot of this type. Amongst these the commonest are *F. oxysporum* and *F. trichothecioides*. However, experiments carried out in Ireland by Pethybridge go to show that there is only one common form of Fusarium, namely *F. cæruleum*, setting up dry rot in that country. In all probability this diagnosis applies equally to Scotland and England.

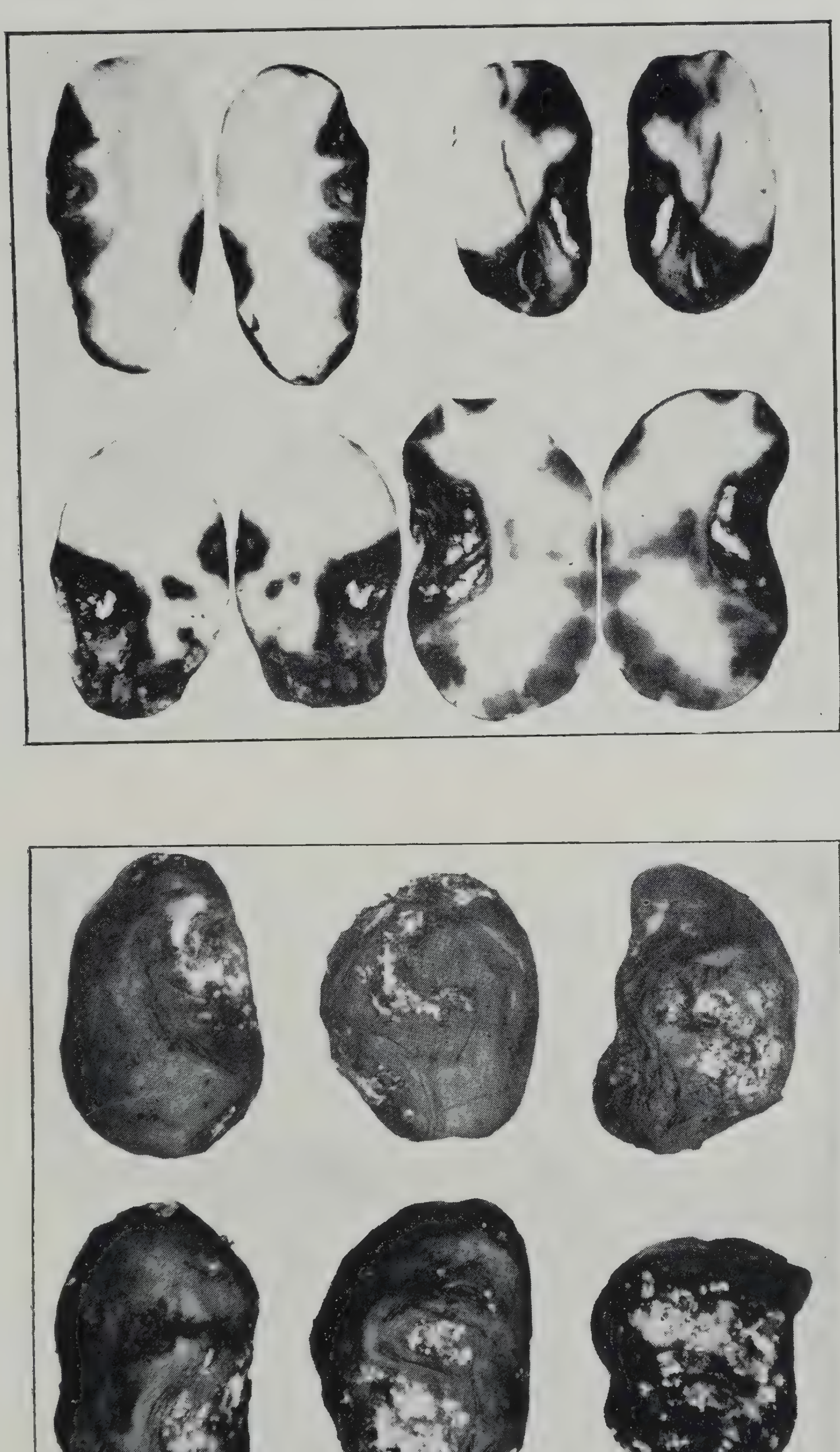
*Symptoms.*—At first the skin at the affected spot is slightly darker in colour than the surrounding area and appears to be somewhat sunken. As the disease progresses the skin becomes wrinkled, and whitish masses of the fungus burst through and grow freely on the surface. Spores are produced in large numbers, and these in turn serve to infect other tubers. The flesh of the tuber in the diseased area is brownish in colour and unduly dry, and frequently shows cavities in which the white mycelium of the fungus grows luxuriantly. As time goes on the water content of the tuber becomes less and less, leaving finally a hard, dry, and abnormally light imitation of the original specimen.

The rotting of the tuber is usually fairly rapid and complete. Occasionally, however, little progress is made, and in consequence partially diseased sets may be overlooked and used for seed purposes. Sets in this condition generally rot in the ground, causing blanks, or if sprouts are developed, weakly and uneconomical plants are produced. The same may happen when tubers are infected at or just before planting; infection arises in some cases by cutting the sets.

*Mode of Infection.*—So far as is known the fungus exists normally as a saprophyte in the soil, and infection can in the first instance be traced to the soil which adheres to the surface of the tubers on lifting. Subsequently, in the pit or store, spores produced from diseased tubers infect healthy neighbouring ones.

The fungus effects an entrance into the tuber in a number of ways, though perhaps most frequently through wounds occurring in the skin. Penetration may also be made through the lenticels, eyes, or young shoots, or scab spots.

Infection may occur at any time, but, as a rule, dry rot becomes serious only when spring approaches. It would seem that tubers become more susceptible to this rot when they begin to sprout.



FUSARIUM DISEASE OR DRY ROT

*Control.*—No measures have proved successful in checking rotting in tubers which are badly infected. Methods of controlling the disease must therefore aim at preventing its transmission to healthy tubers. All diseased tubers are potential sources of infection, and should be immediately removed from the pit or store as soon as discovered. Those only slightly affected may be boiled and fed to pigs, but potatoes in a bad state of decay should be burned.

It has been proved that the spores of this disease can be detected on the walls and in the air of a building in which badly infected tubers are stored. In this connection it may be advocated that, when tubers, either for boxing or consumption, are to be kept in a store, the walls, and also the potato boxes, should be sprayed with a suitable disinfectant. A 2 per cent solution of copper sulphate will suffice for this purpose.

There would appear to be some variation in the degree of susceptibility of many potato varieties to dry rot. Generally speaking early varieties suffer more than late varieties. Pethybridge states that with regard to the former, Epicure, Eclipse, and Windsor Castle are much more resistant than others of this class. In respect to Epicure, observations in Scotland scarcely bear this out. During the winter of 1923–4 many stocks of this variety contracted dry rot to an extraordinary extent. Perhaps this experience was an unusual one, arising from the exceptional summer preceding. If so, then the abnormal conditions might have effected some alteration in the composition of the tuber and destroyed the normal power of resistance to this disease.

In America species of Fusarium other than *F. cæruleum* cause a trouble among growing potatoes analogous to verticillium disease. This form of Fusarium disease is not known to occur in Great Britain, although possibly it is present and is confused with verticillium or some other disease.

## Verticillium Disease.

This disease has been known to attack potatoes since 1879, when it was first described under the name of curl (krauselkraukheit) by Reinke and Berthold. It was diagnosed in Ireland in 1909 by Pethybridge and in 1918 was recognized in certain districts of England. There is reason to believe that it is more common in this country than is generally supposed, but at present it cannot be regarded as a serious trouble. In the past it seems to have been confused with leaf roll and mosaic.

It is probable that this disease is to some extent limited by the prevailing temperature, as it is most evident on light soils especially in warm, dry climates. Britain as a whole does not offer ideal conditions for its development.

*Cause.*—The fungus causing the disease is known as *Verticillium albo-atrum*, R. and B. The mycelium of this organism locates itself in the

wood vessels and interferes with the passage of water from the roots to the leaves.

*Symptoms.*—The choking up of the xylem vessels during early growth results in the foliage becoming wilted. The leaves are usually discoloured and the leaflets rolled. Later they turn brown in colour and, with the other parts of the plant, wither, and thus prematurely die. Sometimes, however, the progress of the disease is slow and the affected plant survives throughout the growing season.

After the death of the affected shaws the fungus spreads from the xylem to the surrounding tissue and rapidly develops. Following this the shaws show long black streaks along their length. These represent the resting stage of the fungus and carry it over the winter. Consequently any such shaws left undestroyed form a dangerous source of future infection.

The yield from plants affected by this disease is usually much reduced, the diminution depending very largely upon the severity of the attack. In bad cases a few small useless tubers is all that can be expected. Although tubers from affected plants do not rot, most of them carry infection in their woody tissue.

An infected tuber will reveal, on cross section at the heel end, a discoloured brownish ring or series of streaks. This discoloration gradually extends towards the rose end. It should be noted, however, that the presence of this ring is not an infallible symptom of this disease as there are others which show a similar browning at the heel end.

If infected tubers are used as seed, the fungus soon migrates from the tubers into the shaw and causes the symptoms already described. Plants arising from badly infected seed are small and stunted, and are of no value as they fail to produce a satisfactory crop.

*Control Measures.*—Probably the infection comes primarily from the soil and enters the plant through its roots. If this is the case the danger of an attack may be obviated or, at any rate, lessened by adopting a longer rotation and thus starving out the fungus.

Only healthy seed should be used, and, although it may be difficult to obtain this by purchase, it is advisable to attempt to secure it by removing and completely destroying all diseased plants during the growing season.

## The Stalk or Sclerotium Disease.

This disease is caused by the fungus *Sclerotinia sclerotiorum*, Mass., and is probably more widespread than is thought, since, in its early stages of development, it is apt to be overlooked or confused with other diseases. In Ireland, where it is known to have occurred in the early eighties of last century, it is described as " white spot ", " falling at the butt ", and " haughing " or " hocking ", and, next to blight, is the most important

potato disease in that country. Most damage is, however, done in the west of Ireland. It is only met with to a small extent in England and Scotland.

*External Symptoms.*—Early in July on the outside of the stalk a whitish mouldy growth appears. The location of the attack varies; often it is near the ground surface, but frequently it is a considerable distance up the stem. The mould, which is the vegetative part of the fungus, develops under favourable weather conditions and forms snow-white spherical or oval cushions on the outside of the shaws. On these a clear liquid like water can sometimes be seen. The cushions become firm and hard, and externally, but not internally, take on a grey or black colour. These are the sclerotia which ultimately fall off the stalks on to the soil. In dry weather the fungus makes its way inside and destroys the living tissue, and white mould in which sclerotia are present may fill up the centre of the shaw. These sclerotia again reach the soil on the decay of the shaw.

The foliage wilts and becomes weak at the point of attack, with the result that the shaws fall over, and the stalks are said to be " haughed ". This haughing often occurs near the ground level, hence the name " falling at the butt ". Plants attacked by this disease early in the season produce few, if any, tubers.

The sclerotia deposited in the soil remain in a dormant or resting stage during the winter. In early summer they germinate, and each one produces on its surface a funnel-, cup-, or disc-shaped structure about the size of a threepenny piece. These spore cups in course of time set free little smoke-like puffs consisting of a mass of minute spores which pass off into the air and settle on the potato stalks and leaves. Smoke puffs are discharged at intervals for as long as two or three weeks, and in this way is the disease transmitted to the potato plants. It has been established by Pethybridge that these spores cannot affect healthy green leaves or shaws. The older yellowing leaves are, however, easily penetrated, and from these the fungus readily passes into the shaw. Wounds on the shaw, left by falling leaves, also serve as a potential mode of infection.

This disease-producing fungus is often associated with another one—a botrytis—which complicates matters to a certain extent.

*Remedies.*—Close planting, crowding of the plants, and early planting increase the risk of loss; consequently where attacks of this disease are apt to be prevalent these points should be noted. Again, all shaws from an affected crop should be burned and, in this way, the attached sclerotia destroyed.

**Botrytis Disease.**

Stalk disease caused by sclerotinia is often, but not necessarily, accompanied by another serious disease caused by *Botrytis cinerea*. The damage

caused by this fungus is not as a rule nearly so great as that brought about by an attack of sclerotinia. The loss, however, is comparatively great in some years. It is found that warm damp weather favours the spread of the disease.

The first external symptom of the disease is the appearance of irregularly shaped dead brown areas on the leaflets, usually of the upper leaves. These at first tend to appear at the apex and proceed uniformly downwards to the base of the leaflet. These dead areas often assume a characteristic V shape, with the point of the V directed towards the base of the leaflet. Owing to the presence of these dead areas a diseased leaflet becomes curled or irregularly twisted and ultimately drops off.

The mycelium growing internally in the tissues passes from a diseased leaflet into a healthy leaflet and soon the whole leaf becomes involved. Finally the parasite reaches the stem by way of the leaf stalk. It then proceeds downwards and attacks the lower leaves. It should be noted that the disease usually proceeds from above downwards and ultimately the whole plant is killed.

In a typical case the dead upper contorted leaves are brownish in colour, the shaw has either a pale green or a yellowish blanched colour. Very often a badly affected shaw retains its upper foliage, while the lower leaves drop off. Consequently the plant becomes top heavy, with the result that the shaw fractures some distance above the ground surface.

During the summer, spores are produced mainly on the dead leaves which have dropped off, but they can be located in wet weather on the diseased areas on an attached leaflet or leaf. These spores serve to spread the disease during the growing season. In wet seasons the disease spreads rapidly, especially if the weather is warm at the same time.

Late in the growing season this disease is characterized by the presence of slightly raised blackened areas both on the outside and on the interior of the more or less blanched shaw. These are the sclerotia or resting forms of the fungus. They remain on the old potato shaw until the following spring, when they germinate and set free a large number of spores which serve to infect that year's crop of potatoes. The spores on germinating gain entrance into the young green leaves, but sometimes the older more or less yellow leaves may be first infected.

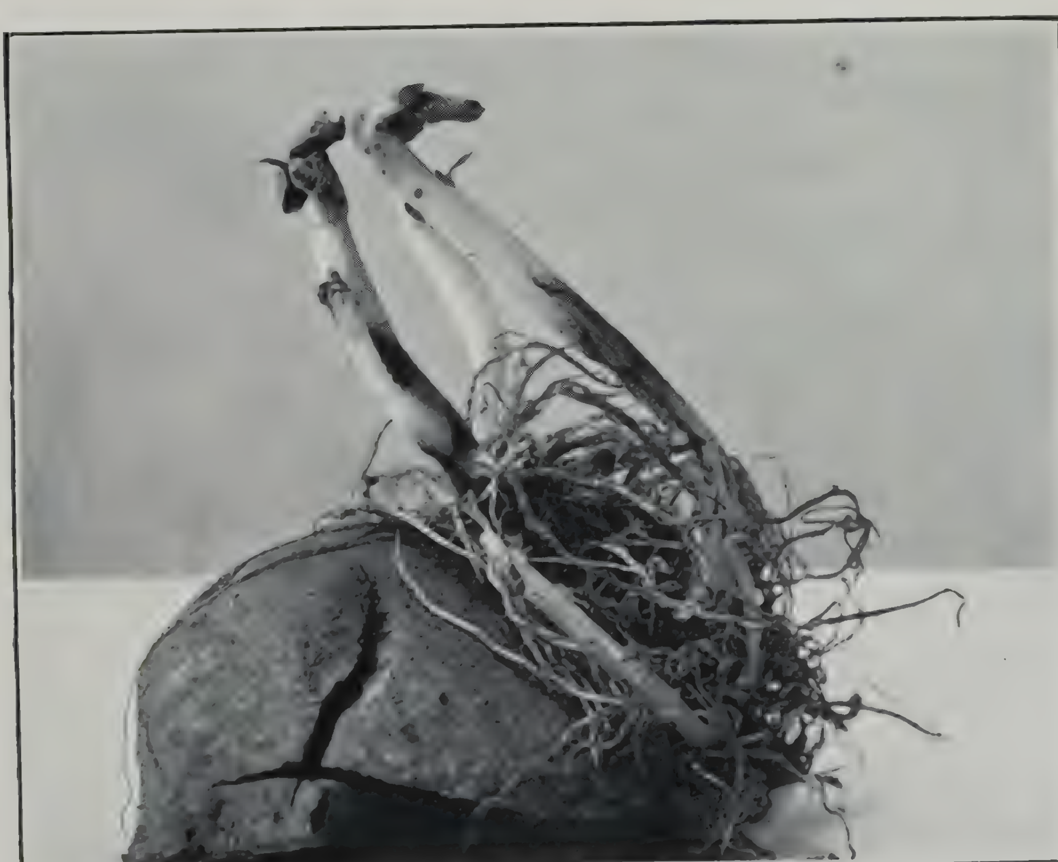
Obviously the disease can be controlled to a considerable extent by burning old potato shaws which harbour the sclerotia. Spraying has no effect, especially if the weather remains wet and warm.

Varieties vary in their power of resistance to this disease. Generally speaking varieties resistant to blight show a similar power of withstanding botrytis.

**Black Scurf, Stem Rot, Rhizoctonia Disease.**

The fungus *Corticum vagum*, B. and C. (Rhizoctonia), attacks a very

SCLEROTIA OF RHIZOCTONIA ON TUBER



SPROUTS OF POTATO ATTACKED BY RHIZOCTONIA

Facing p. 268, Vol. II

wide range of plants, having actually been recorded on 165 species and varieties. It has for long been known to cause a serious disease on potatoes, but in addition it is not infrequently a source of much injury to the following crops: beet, bean, buckwheat, clover, cabbage, carrot, celery, lucerne, tomato, and tobacco.

With regard to the disease as it affects the potato, the damage is mainly confined to the young sprouts which arise from the seed tuber after planting. The infection of the sprouts is in many cases traceable to the presence within the tuber of the resting form of the fungus, termed the sclerotium; in other cases sclerotia in the soil may possibly cause the trouble.

Brown or black spots appear on the sprouts close to the ground surface. These spots result either in the destruction of the tip of the sprout or give rise to a deep wound which may ultimately heal.

The extent of the injury done depends largely upon the weather conditions. The optimum temperature for the development of the fungus is comparatively low, namely 18° C. or 62° F., and consequently in cold weather when growth is slow the disease is much more virulent. Blanks may occur, or the tubers may continue to throw out sprouts until favourable conditions supervene, by which time one or more sprouts reach the surface unaffected. If the weather be warm less injury is likely to accrue owing to the rapid growth of the sprouts coupled with the slower development of the fungus. A soil temperature exceeding 24° C. (75° F.) retards the disease to such an extent that any damage done is negligible.

Owing to the influence of a low temperature in promoting rhizoctonia, it follows that attacks are most serious in countries or districts where, during the early stages of growth of the crop, a comparatively low temperature prevails, e.g. less than 21° C. (71° F.). Thus we find that more damage is done in Scotland than in England, and that, in both, early potatoes suffer most. An attack of the disease may affect in varying degrees the sprouts of as many as 25 per cent of the tubers of so-called earlies.

Plants which have been attacked in their early growth, and have recovered, reveal more or less serious wounds or lesions on their stems just below the ground surface. Aerial tubers are frequently produced during the summer, and certain plants may show foliage symptoms which closely resemble those of leaf roll and mosaic.

The yield is usually seriously reduced, and as a rule the small potatoes occur in a clump close to the base of the stem. The reduction in yield obviously depends on the extent of the injury to the underground stems.

During the later stages of the growing season the fungus produces sclerotia which may be detected by wetting the surface of the tubers. Such sclerotia appear in the form of scurfy, black patches.

There is considerable difference of opinion as to whether the fungus

may cause rotting of the tubers in the pit. The form of rot called "jelly-end rot", perhaps better described as "stem-end rot", is generally ascribed to it.

Control measures will mainly consist in planting sets free from sclerotia. This can be ensured by treating the sets with formalin (strength 1 pt. formalin to 30 gall. water).

Lengthening the rotation, liming the land, and clean cultural methods may likewise be recommended as likely to reduce the loss.

**Skin Spot.**

This is an affection which appears on the surface of the tubers during storage in winter and spring.

It is usually attributed to the fungus *Spicaria solani*. Recent work, however, fails to confirm the accuracy of this diagnosis.

Small dark spots or pimples are formed on the surface. These, after penetrating the flesh to a depth of about $\frac{1}{8}$ in., rupture and give rise to small dark open scabs.

Since the wounds are only skin deep, the damage is not very serious.

Potatoes are subject to many other diseases, some of which are discussed below, but these, as a rule, are not important when considered from the point of view of loss sustained.

**Spindly Sprout.**

As the name implies, thin, spindly, and abnormally long sprouts are formed by affected tubers. The resulting plants are also weak and unproductive.

There is a close relationship between "spindly sprout" and "net necrosis".

**Net Necrosis.**

This is recognized by the presence of netted brown or black areas, which are most evident at the stem end but may extend throughout the whole tuber.

Tubers showing net necrosis produce spindly sprouts and eventually give rise to plants affected by leaf roll. However, it should be emphasized that although this statement is true, yet plants affected by leaf roll do not always show net necrosis in their tubers.

**Black Heart.**

Under certain conditions the centres or hearts of potato tubers become either black or hollow with a black lining to the cavity.

The cause of this trouble is bad ventilation together with the development of a high temperature in the pit or store. A temperature of above 95° F. is particularly liable to cause loss of this form among stored tubers.

**Hollow Heart.**

Hollow cavities, often lens-shaped, may appear in the centres of large-sized tubers, as the result of an abundant rainfall during the growing season. Certain varieties, however, are prone to the formation of such cavities, viz. Ally and Majestic. A varietal tendency of this nature may be partly overcome by close planting.

**Rust.**

This is not a true rust, but is the name popularly applied to the appearance of brown or rust-coloured spots on the leaves. The trouble may be due to various abnormal conditions, such as unduly dry weather early in the season, deficiency of potash in the soil, poor tilth, and bad drainage.

# INSECT ENEMIES OF ROOT AND POTATO CROPS

By L. A. L. KING, M.A., Cantab.

## I. INTRODUCTION

Low-growing and succulent plants, such as potatoes (Solanaceæ), cabbages, turnips, and rape (Cruciferæ), mangolds and beet (Chenopodiaceæ), carrots and parsnips (Umbelliferæ), are liable to injury by various animal foes such as voles and mice, insects, woodlice, millepedes, mites, slugs, eelworms, and the microscopic animals known as " protozoa ".

**Insects** (fig. 1) have horny jointed armour; six jointed walking legs; wings, four, two, or none; and a breathing system of tubes (tracheæ) with openings (spiracles) typically arranged along the sides of the body. Head with jointed feelers (antennæ) and jaws, thorax with the legs and wings, if present, and abdomen, without jointed legs, are three distinct regions. Class Hexapoda.

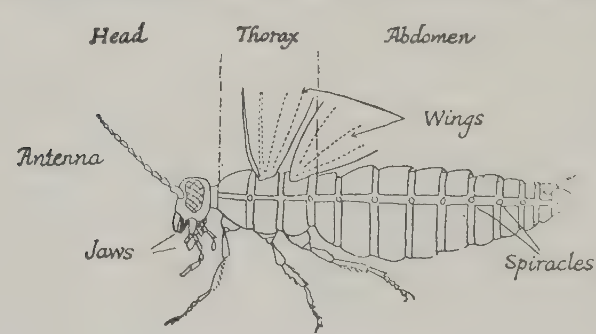


Fig. 1.—Insect Structure

**Woodlice** (fig. 11, p. 281) differ from insects in having fourteen walking legs and in breathing by several pairs of leaf-like " limbs " under the rounded tailpiece or hind-body. They belong to the lobster and crab class (Crustacea).

**Millepedes**—those of importance here (fig. 12, p. 281)—differ from insects in having a long cylindrical body, not divided into thorax and abdomen, but composed of more than eighteen rings, each, except the first three, carrying two pairs of legs. They breathe by spiracles. Class Diplopoda.

The principal kinds of insects concerned in damage to the crops in question are:

*Beetles* (Coleoptera)—recognized by their hard fore-wings (elytra) meeting in a straight line down the back—which have biting jaws;

*Two-winged Flies* (Diptera)—the hind-wings being replaced by small clubs (halteres)—with a sucking trunk (proboscis);

*Butterflies and Moths* (Lepidoptera), with scale-covered wings and coiled sucking proboscis;

*Sawflies* (part of the Hymenoptera), with four membranous wings and cutting ovipositors or saws at the hind end of the body;

*Bugs* (Rhynchota), with a sucking beak containing lancets;

*Thrips* (Thysanoptera), with narrow feather-like wings, with a rudimentary beak and bristle-like jaws;

*Springtails* (Collembola), entirely wingless, with a sucker-like tube below the first abdominal segment, usually with a forked " spring " below one of the two segments before the last. They have small biting jaws, drawn back almost within the head.

The adult or final insect (imago), in all these orders except the Springtails, is usually winged in one or both sexes. It is mainly concerned with reproduction and does little damage to plants except in the case of some Beetles, the Bugs, Thrips, and Springtails.

The feeding, growing insect (larva) is usually the most injurious stage or series of stages.

The principal types of larvæ are:

1. *The Caterpillar* (fig. 2 *a*, *b*, *c*) of Butterflies and Moths, worm-like, with horny head and biting jaws, three pairs of true legs, and from two to five pairs of fleshy " claspers " or false legs beginning on the third part or ring of the hind body and ending on the ninth ring, which is preceded by at least two rings without claspers. Each clasper ends in a horny comb.

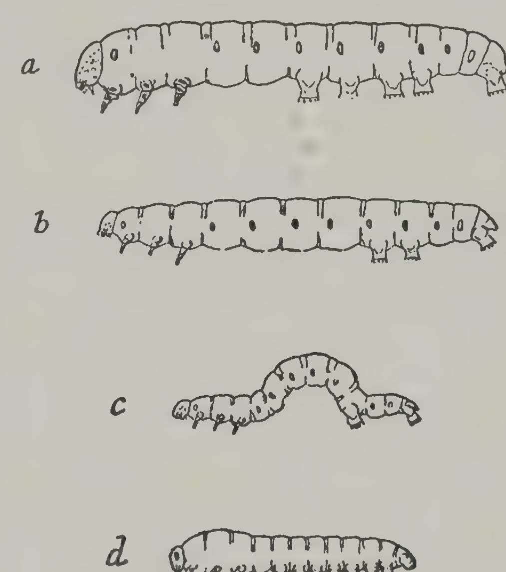


Fig. 2.—Caterpillars and False Caterpillar

2. *The False Caterpillar* (fig. 2 *d*) of Sawflies (e.g. the Turnip Sawfly), caterpillar-like except that more than five pairs of claspers are usually present. These are bluntly rounded and do not bear a comb.

3. *The Grub* (fig. 3) of Beetles, with worm-like body, horny head with biting jaws, and long legs (in predaceous beetles), short, often weak legs (in underground-burrowing, leaf-mining, or wood-boring beetles), or no legs at all (in the snouted beetles or weevils).

4. *The Maggot* (fig. 4) of most Two-winged Flies, soft and worm-like, legless, and without true head, the mouth parts being represented only by a pair of horny hooks. These are usually drawn back into the front rings of the fore-body except when actually in use. The Leather Jacket differs from the true maggot in having a distinct though retractile head with true jaws.

In the case of the Bugs, including the Plant Lice or Aphides, and in that of the Thrips, the larva resembles the adult so closely in general form as to be readily recognizable. No great transformation takes place at the assumption of wings. In Bugs, there is no prolonged motionless stage. In the case of Beetles, Butterflies, and Moths, Sawflies, Two-winged Flies, and Thrips, the larva, when fully fed, becomes motionless as a *pupa* for its final transformation to the winged insect. The pupa in Butterflies (chrysalis) is usually exposed on the plant or on neighbouring walls, fences, or trees. In moths it is usually enclosed in a silk case or cocoon which is frequently hidden underground in an earthen cell. In Sawflies the cocoon is horny, and is usually sticky at first so that it becomes coated with particles of earth in the soil. In Beetles the pupa is usually formed in an earthen cell below the soil surface. In many Two-winged Flies the maggot retains its last larval coat which hardens to form a seed-like pupa case or puparium. This may be formed in the food plant, if suitable for shelter (e.g. a fleshy root), or else in the soil or amongst rubbish.


Fig. 3.—Beetle Grubs

(*a*) Predaceous; (*b*) leaf-mining; (*c*) weevil.

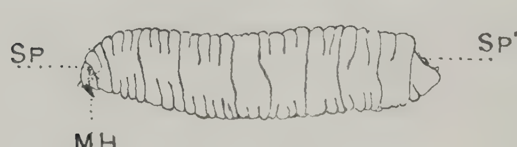



Fig. 4—Maggot

SP., Front spiracle. SP.', Hind spiracles. M.H., Mouth hooks.

A puparium is not formed by the Leather Jackets, which shed their last larval cuticle, leaving the pupa free.

*Mites* (fig. 13, p. 282) are usually minute, just visible to the naked eye as moving specks, white or coloured. Seen under a lens or microscope they show no distinct head, no antennæ, typically *eight jointed legs*. They belong to the Spider class (Arachnida).

*Slugs*, or Shell-less Snails (fig. 14, p. 282), are soft-bodied, slimy animals without limbs or jointed armour, creeping on the flat under-

surface of the muscular body, and breathing partly by the general surface, partly by a lung cavity opening on the back. They have a rasp-like horny tongue-ribbon in the mouth, visible in feeding. Sub-kingdom, Mollusca; class, Gastropoda.

*Eelworms* (fig. 15, p. 284) are minute and usually invisible to the naked eye. Under the microscope they are transparent, writhing worms with a delicate horny covering which is flexible but unjointed and limbless. They are not segmented as earthworms are. The mouth cavity in those attacking plants has a spine used for boring. Sub-kingdom, Nemathelminthes; class, Nematoda.

## II. THE PRINCIPLES OF PREVENTION AND CONTROL

1. Massing together of plants of the same kind tends to attract and to make easy the increase of the injurious animals always present in nature. This is unavoidable in farming. It can be met by (*a*) protection of wild birds, almost all of which attack insects at the most important seasons. Nesting copses, even nesting boxes, and berried hedges for winter food may be provided. (*b*) Knowledge of the likely insects, &c., injurious to the particular crop and suited to the particular area, and watchfulness for the first sign of their attack, however slight. This involves ability to recognize at least the kinds of insects, &c., in different stages, and having measures in readiness so that no time may be lost. Even chemical insecticides (see para. 7, p. 276) are of most value when used preventively.

2. Repetition of the same or allied crops on infested or adjoining ground helps to keep the pests going from year to year. This is avoided by rotation of crops not botanically alike, since the same insects, &c., usually attack all cultivated plants of the same family.

3. Weeds in fields and hedge bottoms, refuse of crops, heaps of manure, hay and rubbish, boards, tarpaulin, clods, &c., give food, breeding places, and winter shelter to the insects, &c. This is prevented by clean farming, by early autumn ploughing to break up winter shelter and expose insects, &c., to birds and to the weather, and by early spring ploughing and harrowing to keep fallow and starve out the insects.

4. Insufficient or unsuitable manuring delays and weakens the plants and makes them less able to outgrow injury. Farmyard manure may be a danger where soil is infested, since it attracts egg-laying females, feeds some larvæ, and shelters pupæ. On the other hand, kainit, lime, and nitrate of soda are actual insecticides in some cases.

5. Time of sowing or of planting may have to be varied, early or very late, so that the weakest stage of the plant may not occur at the strongest or most injurious stage of the insects, &c. Early or late varieties of plants may be indicated as suitable on these grounds.

6. When an attack is in progress the best method of destruction is

one which actually catches the insect, e.g. hand picking or lifting and burning infested plants.

7. When an attack is in progress the use of chemical insecticides may be necessary. It is liable to be troublesome and expensive, also ineffective unless applied with a sufficient knowledge of the habits and life history of the insect to be attacked and of the nature and action of the substance employed. Spraying, for instance, is a " bombardment " of the enemy, producing " losses " but seldom extermination, and requiring repetition as those losses are " made good ".

Insecticides in general may be divided into:

(*a*) *Stomach poisons* or food poisons for insects with biting jaws, e.g. arsenical sprays, washes or dusts, and poison baits.

(*b*) *Contact poisons* or body poisons and suffocants for sucking insects which do not eat the surface of leaves, e.g. nicotine, petroleum, soap.

(*c*) *Fumigants* or breath poisons applied as vapours or gases for insects underground or not easily accessible, e.g. naphthalene, carbon disulphide.

## III. THE CROPS AND THEIR PRINCIPAL PESTS

### A. **Potatoes (the Nightshade Family, Solanaceæ).**

The tubers are attacked by: Beetle Grubs, such as Wireworms, White Grubs; Fly Maggots of the special type Leather Jackets; Caterpillars, especially Surface Caterpillars and the underground ones of Swift Moths; Springtails; also by Woodlice, Millepedes, Bulb Mites, Slugs, and Eelworms.

The foliage is attacked by: Beetles and their Grubs, such as Colorado Beetle, Flea Beetles; by Bugs, such as Leaf Bugs, Frog Flies, and Greenfly (Aphides); by Thrips; by Springtails.

#### 1. **Beetle Grubs.**

**Wireworms.**—These are described in Vol. I, pp. 337, 338. They occur particularly after grass or grain crops.

*Symptoms.*—Plants look sickly and die without apparent injury above ground. The grubs are found in the perforated tubers.

*Wild Food Plants.*—Especially the roots of grasses.

*Control.*—See " Principles of Prevention and Control " above, p. 275, par. 3, also Vol. I, p. 338.

**White Grub.**—See " The Cockchafer ", Vol. I, p. 339. They occur particularly after grass or grain crops.

*Symptoms.*—Very similar to those of wireworm. The grubs are found in the soil close by.

*Wild Food Plants.*—Especially the roots of grasses.

*Control.*—See above, p. 275, par. 3, also Vol. I, p. 341.

**Colorado Beetle** (*Leptinotarsa decemlineata*), fig. 5.—A serious pest in the United States and Canada. A colony was found in Tilbury in 1901 and 1902, but was exterminated. Recently it has been a source of anxiety in France.

*Description.*—Grub, about $\frac{1}{2}$ in. long when full grown, soft, swollen, hump-backed. Colour, orange, with head, legs, and hind part of first segment black. Two rows of black spots along the sides. Appears in early summer. Duration 16 to 21 days.

*Pupa.*—Mummy-like with leg- and wing-rudiments. Found in the soil. Duration, a week or more.

*Adult* (*Beetle*).—About $\frac{2}{5}$ in. long and $\frac{1}{3}$ in. wide, yellow to orange, with five black lines along each wing-cover.

*Egg.*—Almost cylindrical, orange, nearly $\frac{1}{8}$ in. long.

*Crops Attacked.*—Potatoes, tomatoes.

*Symptoms.*—Grubs and beetles eating the leaves.

*Life History.*—The adults winter in the soil or among rubbish. In early summer eggs are laid in clusters on the under side of the young leaves, upright; hatch in a week or more. The larvæ feed, drop to the earth, and pupate in smooth oval cells. A second brood and even, in suitable temperature, a third may be produced.

Fig. 5.—Colorado Beetle and Grub

*Wild Food Plants.*—Members of the potato family, such as Nightshades, Thorn Apple; also Thistles and Hedge Mustard, and many other weeds.

*Control.*—When the insect is discovered the Board of Agriculture must be notified in terms of the Destructive Insects and Pests Order of 1908. The insects may be shaken off the plants into pails of paraffin.

In America *Paris Green* (aceto-arsenite of copper) is used dry as a " dust ", mixed with fifty times its weight of flour or air-slaked lime, also as a " spray " in the proportions of 1 lb. Paris Green to 1 lb. freshly slaked lime to 42 gall. (British) of water.

*Lead Arsenate*, mixed with fifty times its weight of agricultural gypsum, may be used as a dust, or alone (2 lb. of powder or 4 lb. paste to 42 gall. of water) as a spray, which is less destructive to foliage than is Paris Green. Insoluble arsenical poisons can safely be used up to one week before the potatoes are lifted. In the soil the insects are dealt with by injection of carbon disulphide.

**Flea Beetles** (Halticidæ).—Of various species (see section B, p. 285); may damage young foliage in spring, or may perforate the leaves later, in dry seasons. They can be controlled by spraying with Bordeaux Mixture (lime and copper sulphate), which is used also as a protection against fungus blight.

### 2. Fly Larvæ.

**Leather Jackets.**—See " The Daddy-long-legs ", Vol. I, p. 343. They occur especially after grass and clover in damp soil.

*Symptoms.*—Very similar to those of wireworm. The maggots may be found inside the tubers, in which their perforations are a little larger than those of wireworm.

*Wild Food Plants.*—Especially grasses and clovers.

*Control.*—Prevention, after grass or clover, by close grazing, followed by ploughing in July or early August. Gas-lime (3 to 4 tons per acre) followed by autumn ploughing. During attack, hoe to destroy the grubs or to expose them to birds. See also Vol. I, p. 345.

### 3. Caterpillars.

**Surface Caterpillars or Cutworms.**—These are larvæ of various " Owlet " or Noctuid Moths, and all feed at night beneath or at the ground surface, lying concealed in the soil by day.

Fig. 6—Turnip Moth and Caterpillar

*Description.*—Fleshy caterpillars, length 1 in. or more, brown, grey, or greenish in colour. That of the Turnip Moth, *Agrotis* (*Euxoa*) *segetum* (fig. 6), has dark spiracles smaller than the neighbouring spots, that of the Heart-and-Dart (*Agrotis exclamationis*) has black spiracles larger than the spots. That of the Great Yellow Underwing (*Triphæna pronuba*) is the largest, up to 2 in., reddish brown or grey to greenish with lighter under surface, a light stripe down each side, and oblique black stripes just above it.

The moths fly by night and feed on the nectar of flowers; are heavy bodied, with dark fore-wings bearing a distinctive kidney-shaped mark.

*Crops Attacked.*—Potatoes, beet and sugar beet, mangolds, turnips, rape, also wheat and other autumn-sown cereals.

*Symptoms.*—Stems are cut through, close to the ground, or plants appear sickly without visible cause. Tubers or roots show large perforations $\frac{1}{4}$ in. in diameter. The caterpillars may be found by day in the soil, or by night in the act of feeding.

*Life History.*—Moths appear June to July, and lay eggs on leaves or stems of many weeds and cultivated plants, also probably on stable manure. Caterpillars emerge in ten to fourteen days. In warm seasons these may be full fed by end of July and become pupæ, from which a *second flight* of moths may emerge in two or three weeks, lay eggs, and give rise to a *second brood* of caterpillars. These, and survivors from the first brood,

winter as larvæ in the surface soil, feeding if the weather is mild. If the winter is severe they go deeper and are less exposed to damp and to parasitic fungus, so that a hard winter *favours* the succeeding moths. Pupation occurs from February to April for the first flight of moths in June.

*Wild Food Plants.*—Grass, weeds of all kinds, and even the stems of young forest trees.

*Control.*—See "Principles of Prevention", p. 275. Winter wheat should not be sown where potatoes or mangolds have been badly attacked. Rolling, or pasturing cattle or sheep on the ground, will tend to destroy the larvæ by crushing.

Stable manure, in preparation for planting, should be worked in as long as possible before the time, and completely covered to avoid attracting the egg-laying moths.

In wet ground kainit kills the caterpillars. Poisoned bran mash (Paris Green, ½ lb., or lead arsenate paste, 2 lb., mixed with 50 lb. bran and 2 gall. water with ½ lb. sugar or salt, worked together) may be applied in the evening immediately after the ground has been prepared, but before sowing or planting, at the rate of 10 lb. to 50 lb. per acre. Cut clover dipped in lead arsenate (½ lb. paste to 10 gall. water) may be placed along the borders of fields to be protected. In infested areas poisoned baits should be used every spring to protect the crops. During attack, hoe or harrow to disturb the larvæ and expose them to birds. Hand-picking should be used where possible.

Fig. 7.—Garden Swift Moth and Caterpillar

**The Garden Swift Moth** (*Hepialus lupulinus*), fig. 7.

*Description.*—The caterpillars feed underground. The body is white with black spiracles and scattered dark spots from which "hairs" arise singly. The head and a shield on the first body-segment are brown. The fully fed caterpillar is about 1 in. long. The pupa is red or pale brown and shining, with darker head and wing-cases. The segments of its hind-body have toothed horny ridges. The pupa is enclosed in a silk cocoon which it leaves, to work its way out of the ground before emergence of the moth.

*The Moth* measures 1 in. to 1½ in. in wing-spread. Its fore-wing is brown with a bent white band crossing it and a white spot in front; hind-wings darker. The female is lighter coloured than the male and not so distinctly marked. The moths fly at dusk.

*Egg.*—Round, greenish at first, turning black.

*Plants Attacked.*—Potatoes, parsnips, lettuce, oats, peas and beans, strawberries, &c., and many cultivated flowering plants.

*Symptoms.*—Wasting of the plants above ground. The tubers or roots are gnawed and scooped out by the larvæ.

*Life History.*—Moths emerge in May and June. The female drops her eggs among herbage as she flies. Caterpillars feed on through summer, autumn, and winter. Pupation, April, May, June.

*Wild Food Plants.*—Grasses, Horehound, Dead Nettles, Plantain, Dock, &c.

*Control.*—Removal of weeds; working of the soil to expose the larvæ and pupæ to birds; naphthalene, at the rate of 1 oz. per square yard in affected patches, scattered and dug in in autumn and spring.

## 4. Sucking Insects or Bugs (Rhynchota).

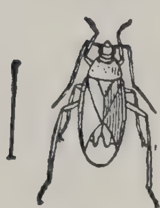


Fig. 8.—Potato Bug

**Potato Bug** (*Lygus* (*Phytocoris*) *solani*), fig. 8.—A small, green, flat-bodied insect about $\frac{1}{4}$ in. long, winged in the adult, with the inner two-thirds of the fore-wing thickened. It is most abundant in August, and feeds on the sap of the leaves by means of its beak containing piercing lancets. This starves the plant and checks its growth, causing yellowing of the leaf surface attacked. Bordeaux mixture, alone or mixed with nicotine sulphate (1 in 1200), used as a spray is recommended.

Fig. 9.—Potato Frog Fly

**Potato Frog Fly** (*Eupteryx solani*), fig. 9.—A pale green insect about $\frac{1}{6}$ in. long, with large, almost veinless wings in the adult, is found hopping about potato leaves in sunshine during August and September. Its attack and the methods of control are similar to those relating to Potato Bug above. These bugs probably feed on many wild plants of the Nightshade family and also on Docks (*Rumex*). The removal of weeds is the best general protection.

**Greenfly or Aphides** (see p. 295) are occasionally abundant. Their chief importance is as carriers of the infective virus of the leaf roll and mosaic diseases.

a

b

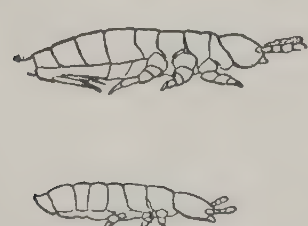


Fig. 10.—Springtails
(*a*) Achorutes; (*b*) Lipura.

## 5. Other Insects.

Other insects occasionally injurious are Thrips (Thysanoptera) (see Vol. I, p. 351) and Springtails (Collembola). Of the latter a purple *Achorutes* about $\frac{1}{12}$ in. long with a "spring" projecting from the under side of the fourth abdominal segment, and *Lipura* (*Onychiurus*) *ambulans* (fig. 10), a white species without a spring and only about $\frac{1}{16}$ in. in length, commonly attack the tubers, scraping away the outer skin and exposing the "flesh" to fungus attack.

Unslaked lime destroys them by drying up the soil, since they breathe by their skin and not by tracheæ.

## 6. Other Animal Pests often mistaken for Insects.

**Woodlice or Slaters** (Crustacea).—The Pill Woodlouse (*Armadillidium vulgare*, fig. 11) is occasionally destructive to potatoes, field beans, &c. It is slatey grey, smooth, shiny, strongly arched, and can roll up into a complete ball. It is found in the soil or amongst rubbish; feeds at night, gnawing the surface of potatoes and hollowing the interior; winters at the roots of various plants or in manure heaps, and breeds in rubbish.

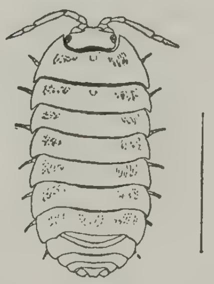


Fig. 11.—Pill Woodlouse

*Control.*—Its feeding habits and method of attack on tubers being so similar to those of surface caterpillars, many of the measures recommended for those may be applied; e.g. the use of poison baits. Removal of rubbish, and breaking up of clods will reduce the shelter. Unslaked lime and Paris Green have been used as a dust between the plants with success.

**Millepedes or False Wireworms.**—The Spotted Millepede (*Blanjulus pulchellus*, fig. 12) is a slender species about ½ in. long, yellowish with a row of dark red or purple spots along each side, body-rings about forty.

*Crops Attacked.*—Potatoes and various roots and bulbs.

*Symptoms.*—General weakness of the plant, scab-like wrinkling and cracking of the skin and rotting of the flesh of the tuber in which the Millepedes are found. They bore into the flesh and hollow out the decaying tuber, or merely gnaw the surface, giving entry to earthworms, slugs, or fungus.

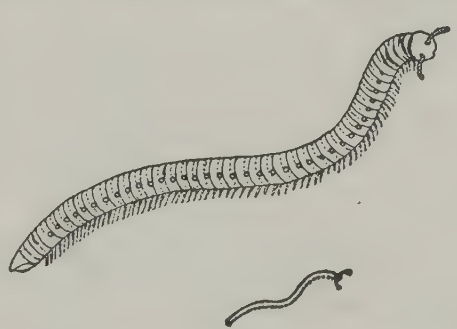


Fig. 12.—Spotted Millepede, enlarged and natural size

*Life History.*—Not worked out for this species, but in the larger, grey *Julus terrestris* eggs are laid in early summer in a spherical earthen nest underground, which is closed after sixty to one hundred eggs have been deposited. The young, with only three pairs of legs at first, hatch in a fortnight. Additional rings with two pairs of legs each are added in front of the last segment in the course of growth.

*Wild Food Plants.*—Almost all plants with fleshy roots or bulbs, also decaying vegetable matter and leaf mould.

*Control.*—Clear away the remains of root crops after gathering. Burn all vegetable refuse. Disturb the nesting-places by cultivation. Dig into

the soil, in autumn, lime or gas-lime (1 ton per acre). Soot may be used at any time. Tobacco dust has been found successful in America.

Trapping with hollowed mangolds or turnips, lightly buried and lifted regularly for destruction of the catch, can be recommended where practicable.

**Mites.**—Bulb Mite (*Rhizoglyphus echinopus*), fig. 13, visible only as a moving light speck, belongs to the Cheese Mite family. It is about $\frac{1}{50}$ in. in length, yellowish white tinged with pink, having a few long hairs on the body and legs. The legs and mouth parts are red. It requires moisture since skin-breathing is the rule.

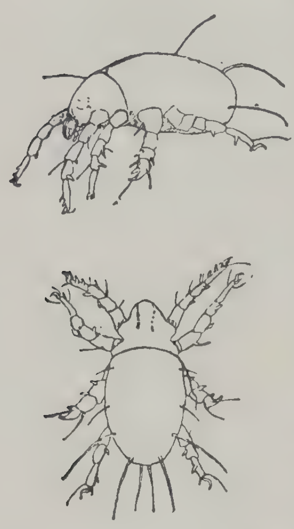


Fig. 13.—Bulb Mite

*Crops Attacked.*—Potato, onion, and others with fleshy stems, bulbs, and roots. It is seldom injurious on a large scale.

*Symptoms.*—Leaves turn yellow; plants fail to flower; spots on the tubers, &c., indicating the feeding place; presence of the mites.

*Nature of Attack.*—The mites perforate the parts attacked with their mouth-pincers and suck the juices.

*Life History.*—Lay eggs in the interior of the plant, from each of which hatches a six-legged larva, which moults to become an eight-legged immature form known as a *nymph*. Some of the nymphs have on the under side of the body suckers by which they attach themselves to passing insects, spiders, &c. This stage is known as the *hypopus*. It does not feed and can resist drying up. Carried to new feeding places it moults and becomes an active adult.

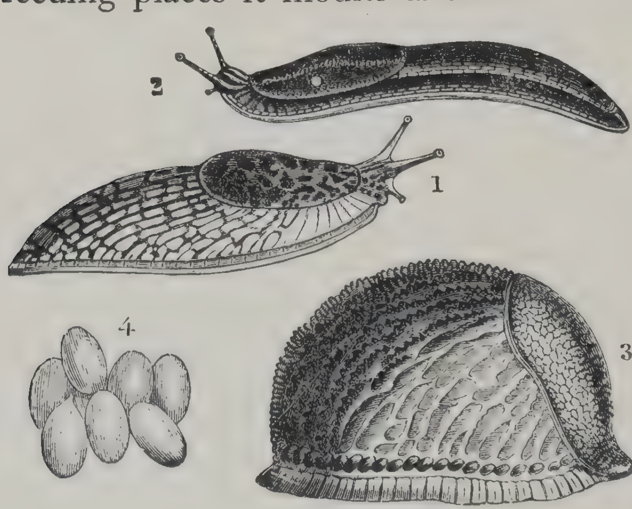



Fig. 14.—Slugs
1, Milky Slug. 2 and 3, Black Slug. 4, Eggs.
(After Curtis.)

*Wild Food Plants.*—Not ascertained, but probably all bulbous.

*Control.*—Burning infested plants is recommended. Flowers of sulphur may be sprinkled about the roots, or dilute paraffin emulsion. Gas-lime would probably eliminate the mites from the soil.

**Slugs or Snails** (Mollusca).—The Field Slug or Milky Slug (*Agriolimax agrestis*, fig. 14), about $1\frac{1}{2}$ in. in length, usually grey mottled with brown, and other species, require moisture since they breathe largely by the skin. They therefore feed mostly at

night or dusk or, in the day time, after heavy rain. By day in dry weather they lie concealed under stones, clods, old iron, boards, sacking, &c.

*Crops Attacked.*—Potatoes, cabbages, and many others.

*Symptoms.*—Holes appear in the parts attacked and tracks of slime are seen leading to the lair.

*Nature of Attack.*—Rasping through the outer skin of tubers, roots, stems, and leaves, they hollow out the flesh.

*Life History.*—Rounded, gelatinous, colourless eggs, differing in size from a pin's head to a small pea, according to species, are laid in clusters under stones, logs, and rubbish. The small slugs hatch out in three to four weeks. The adults winter in similar situations or in hollows, lined with slime, in the earth. They are found also in stable manure.

*Wild Food Plants.*—Grass and almost all weeds, also fallen leaves of trees.

*Control.*—Draining damp land. Avoidance, for a time, of organic manure, where they are abundant. Neighbouring copses or spinneys should be shut off with a trap trench containing lime or tar. Ducks, poultry, and wild birds such as thrushes, blackbirds, starling, lapwing, should be allowed free play on the land. Dry dressings of soot and lime, salt and lime, lime and caustic soda (96 parts of the lime to 4 parts of caustic soda applied during their feeding times), and powdered coke may prevent their moving about.

**Eelworms** (Nematoda). Root-knot Eelworms (*Heterodera radicicola*).

*Description.*—Invisible to the naked eye; about $\frac{1}{75}$ in. in length. The males worm-like, the mature females rounded or pear-shaped.

*Crops Attacked.*—Potatoes, tomatoes, and other fleshy-stemmed plants.

*Symptoms.*—Drooping and yellowing of the foliage, limpness of the stem; knot-like swellings about the size of a pin's head on the roots; presence of the Nematodes in these when examined under the microscope. In Germany in 1921 a heavy infestation occurred, leaves were blackened, roots in a state of dry rot, tubers small.

*Nature of Attack.*—The Nematodes bore in from the soil and the plant responds by active growth in the form of galls at the point of irritation. This growth, together probably with the production by the worms of an active poison, lowers the vitality of the plant.

*Life History.*—The female lays eggs, or perhaps more frequently brings forth active young, in the galls. These enter the soil and eventually reach new plants.

*Wild Food Plants.*—No systematic survey has yet been made of these in this country. It is possible that the young may survive for a length of time merely in the soil if sufficiently moist and abounding in organic

matter. It is probable also that they can lie dormant for a length of time in dry soil owing to the presence of a cuticle on their outer surface, which can be either shed or retained as a sheltering capsule in their early stages. In America, however, thorough drying of the soil has been found to kill the animals.

*Control.*—Temporary avoidance of farmyard manures. Sulphate of potash 4 cwt. per acre, or kainit 1 to 4 cwt. per acre, has been found effective as a germicide. All plants seriously affected should be burnt. Deep ploughing tends to bury the eelworms at a depth at which they cannot survive.

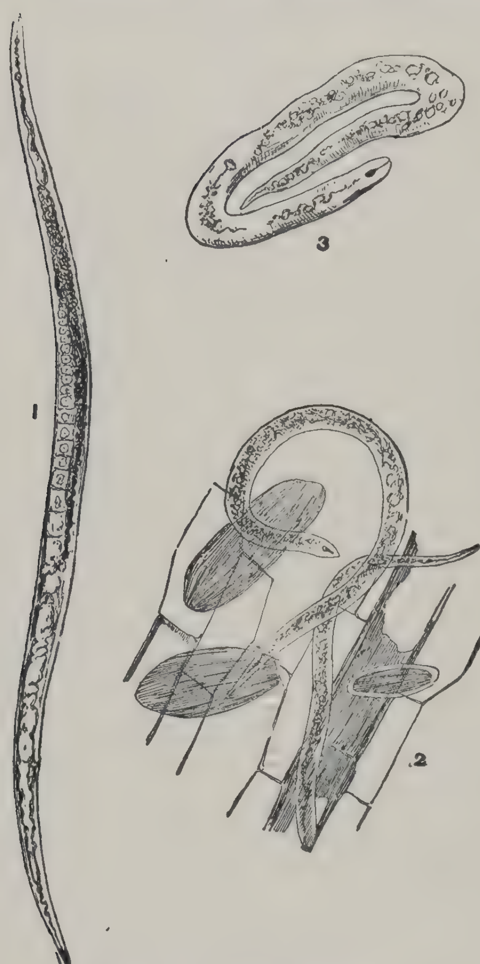


Fig. 15.—Stem Eelworm
1, Female 2, Eggs and worms in plant tissues. 3, Young.

Stem Eelworm (*Tylenchus* sp.) (fig. 15) has been found to produce eelworm rot in tubers, resembling in effect the phytophthora rot produced by a fungus. The rind is pitted and discoloured and brown spots occur under the pits, but microscopic examination shows that the thread-like mycelium of the fungus is absent whilst clumps of Nematodes are present. Length up to $\frac{1}{25}$ in.

*Crops Attacked.*—Potatoes, clover, oats, onions, and probably a number of others, though the identity of the species of Eelworm concerned has not been definitely ascertained.

*Symptoms.*—These have been sufficiently indicated above in the case of potatoes. There is a tendency to stunting of growth above ground and there may be yellowing of the foliage.

*Life History.*—In general similar to that of *Heterodera.*

*Wild Food Plants.*—See remarks under *Heterodera.*

*Control.*—A rotation should be avoided in which successive crops are of a type liable to Eelworm attack; peas, beans, and vetches (except kidney vetch) do not appear to suffer from Eelworm. For other methods of control see under "Root-knot Eelworm" above, p. 283.

### B. Cabbages, Kale, Marrow-stem Kale, Kohl-Rabi, Swedes, Turnips, Rape (Family Cruciferæ).

The species and varieties of this family are liable in different degrees to attacks as below.

(*a*) The roots by:

*Beetle Grubs*: Flea Beetles, Gall Weevils, Mud Beetles.
*Fly Maggots*: Root Fly, Carrot Fly.
*Caterpillars*: Surface Caterpillars.
*Springtails*: Lipura and Achorutes.

(*b*) The stems and leaves by:

*Beetle Grubs and Beetles*: Flea Beetles, Blue Beetles.
*Fly Maggots*: Leaf Miner Flies, Gall Midges.
*Caterpillars*: White Butterflies, Cabbage Moth, Diamond-back Moth.
*False Caterpillars*: Turnip Sawfly.
*Bugs*: Snowflies, Aphides.
*Springtails*: Smynthurus.

(*c*) The flowers and fruits by:

*Beetle Grubs and Beetles*: Flower Beetle, Weevils (*Ceuthorhynchus assimilis*).
*Fly Maggots*: Crucifer Midge.
*Thrips*.

## 1. Beetles.

### Flea Beetles.

*Description.*—Small jumping and flying Beetles with thick " thighs " on the hind-limbs: (*a*) olive-black with yellow stripe on each wing-cover: *Phyllotreta nemorum*, $\frac{1}{8}$ in. long, with brownish yellow legs (fig. 16); *P. undulata*, $\frac{1}{12}$ in. long, with nearly black legs. (*b*) Black: *P. consobrina*. (*c*) Blue: *P. cruciferæ*. (*d*) Metallic greenish black: *Plectroscelis concinna*. (*e*) Metallic bluish green: *Psylliodes chrysocephala*. Larvæ about $\frac{1}{8}$ in. long, yellowish white with brown head and six legs.

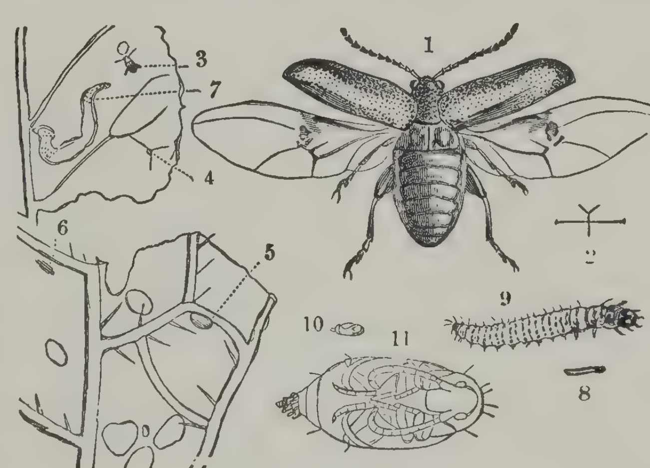



Fig. 16.—Flea Beetle

1. *Phyllotreta nemorum*, enlarged. 3–7, Stages on leaf. 8–9, Larva. 10–11, Pupa. (After Curtis.)

*Crops Attacked.*—All crucifers, also mangolds.

*Symptoms.*—Seed-leaves (cotyledons) eaten by the adults, rough leaf perforated as if by shot-holes.

*Nature of Attack.*—The chief attack is that of the adults (see above).

In some species (e.g. *P. nemorum*) the grubs mine the leaves, others (*P. undulata*) feed on the roots, others (*Psylliodes*) burrow in the stalks.

*Life History.*—Differs in detail in the different species. Eggs microscopic, white, laid June, July, August, in the soil, on the roots, or on under side of leaves. Larvæ hatch in about a week. Length of larval life varies with species and with weather conditions. Pupate, some in the soil, some in the mines on the plant. Several generations in a season. The adults winter amongst refuse in hedge-bottoms, heaps of refuse, stacks, &c.

*Wild Food Plants.*—Especially cruciferous weeds, such as Charlock, Wild Mustard, Wild Radish or Runch, Shepherd's Purse, but also nettles and grass.

*Control.*—See " Principles of Control ", p. 275. Use fresh seed for rapid germination. Soak the seed for a night in petroleum, drain and mix with dry sand. Sow thickly. Water during dry periods but not in sunshine. During attack dust the leaves with soil, by hoeing or by driving sheep, or with powdered naphthalene, soot and lime, or basic slag. Disturb the beetles by a raking-machine from which the rake has been removed and sacks are suspended from the beam, covered to 6 in. from the ground with sticky " banding composition " (tanglefoot) or with tar. The beetles rise and are caught. Spray with paraffin emulsion (paraffin, 2 pints., soft soap, 1 lb., boiling water, 10 gall.).

**Rape Beetle or Turnip Flower Beetle** (*Meligethes æneus*), fig. 17. —An insect of uncertain reputation, since much damage attributed to it may be due to other beetles, such as the Seed Weevil (*Ceuthorhynchus assimilis*) mentioned below. Meligethes is even believed to be beneficial in that it assists pollination of the flowers.

*Description.*—The larva is about $\frac{1}{6}$ inch long, white, with brown head and six short legs. The beetle is about $\frac{1}{12}$ in. long, greenish black.

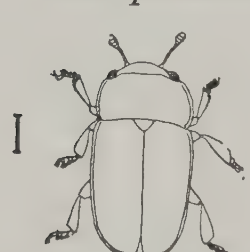


Fig. 17.—Rape Beetle

*Crops on which it is Found.*—Rape, turnip.

*Symptoms.*—Beetles in the flowers, grubs on the leaves of flowering shoots and in the bud and the seed-pods. Both larvæ and beetles eat the pollen, apparently without injury to the plant, but when a cold spring has delayed the opening of buds the beetles may bite into these and so cause harm, and the second flight of beetles may injure the reproductive organs of the blossom and so decrease the seed yield.

*Life History.*—There are two generations in the year. Beetles appear in spring and lay eggs singly in the buds of rape and turnip flowers. Larvæ hatch in a week, feed and pupate in the soil. Second flight of adults may emerge from April to end of June. These winter in the earth or under rubbish.

*Wild Food Plants.*—Various weeds, especially Crucifers.

*Control.*—Destruction of weeds; selection of early-flowering varieties of rape. The beetles may be collected in early morning or on a dull day by boys with wet nets over which the plants are shaken, the catch being emptied into bags, subsequently dipped into boiling water. In this way the more injurious beetles will be destroyed together with Meligethes.

**Mustard Beetle or Blue Beetle** (*Phædon cochleariæ*), fig. 18.

*Description.*—Larva at first yellow, later spotted with black, $\frac{1}{4}$ in. long when full fed. Pupa yellow. Beetle $\frac{1}{8}$ in. long, rounded, deep metallic blue.

*Crops Attacked.*—Mustard, also cress, watercress, turnips, rape, and cabbage. Mustard infects neighbouring turnip and cabbage crops.

Fig. 18.—Mustard Beetle
1 and 2, Eggs. 3, 4, 5, Larva, natural size and enlarged. 6 and 7, Beetle.

*Symptoms.* — Leaves eaten, stems scraped, flowers undeveloped, or fruits stunted. Beetles and grubs found on the shoots.

*Life History.*—Two generations in the year. Adults winter in stems of mustard stubble, also in hedge bottoms and rubbish. In spring they fly to the rough leaf of young mustard, feed, and lay eggs on under side of leaves in May and June, then die. From the eggs emerge grubs, which feed for two or three weeks, drop to the ground and pupate. Second flight of beetles emerges in about ten days and attacks leaves. Their eggs yield larvæ which become beetles from late July to early September. These shelter for winter when the crop is cut.

*Wild Food Plants.*—Horse radish and probably other Crucifers.

*Control.*—Prevention: rotation, clean farming, and watchfulness. Spray the leaves at first attack with lead arsenate (8 oz. paste moistened to a cream and made up with water to 10 gall.). During attack the beetles may be swept off the young plants by sacking, attached to an axle with wheels, so as to touch the tops of the plants as it passes along the rows; trays just wide enough to pass between the rows are suspended from the axle, containing paraffin or tar to catch the beetles. Cut early to save the seed. Burn the straw and stubble as soon as possible.

**Turnip and Cabbage Gall Weevil** (*Ceuthorhynchus pleurostigma*, Marsh = *C. sulcicollis*, Gyll.), fig. 19.

*Description.*—Larva shining yellowish white with brown head, legless, body curved, up to $\frac{1}{8}$ in. or more in length. Beetles $\frac{1}{12}$ to $\frac{1}{8}$ in. long, dull black with scattered whitish scales, and having a narrow, down-curved "snout" carrying elbowed antennæ.

*Crops Attacked.*—Turnip, cabbage, Brussels sprouts, savoy, kohl-rabi, mustard, rape.

*Symptoms.*—Starvation of the " head " of leaves. Rounded, marble-shaped galls on the roots, not finger-like and not rotting as in club-root disease. Grubs found in cavities inside.

*Life History.*—According to Isaac (*Journal of the Ministry of Agriculture*, London, March, 1922) the more important race of Beetles appears in early June. These feed on the leaves, stems, flowers, and pods of turnips and cabbages, also on the leaves of Charlock and Hedge Mustard. In late August they lay eggs on the roots. In five days or more the larvæ hatch out and enter the root, which responds by forming galls. The larvæ winter in these and resume feeding in spring. They pupate in the soil about the end of April. Beetles emerge in late May or early June, and lay eggs on turnips, cabbage, &c. Charlock sustains a separate spring race of the Beetles of which the next generation winters in the adult state.

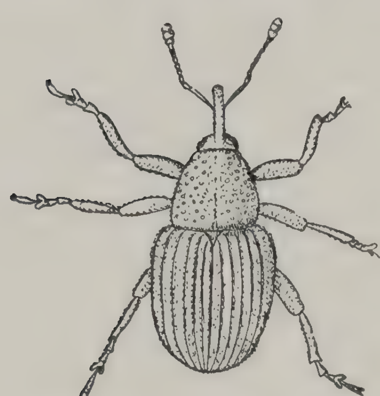


Fig. 19.—Turnip Gall Weevil

*Control.*—Destroy cruciferous weeds, especially Charlock and Hedge Mustard, which feed the adults. Affected turnips should be used early before the larvæ escape. Cabbage stumps and roots should be burnt. Poultry may be run on the ground after the crop is cleared and the stumps pulled.

Deep ploughing or digging-in gas-lime (1 to 2 tons per acre) will destroy larvæ or pupæ in the soil if the roots have been left in too late.

Other species of Cabbage and Turnip Weevils are: (*a*) the Seed Weevil (*Ceuthorhynchus assimilis*), which attacks, as larva, the seed pods, which discolour and open prematurely, allowing the grubs to escape to the ground. From their pupæ beetles emerge in two to four weeks (in Germany) and attack buds and flowers. These adults winter in the stubble or surface soil. The eggs are inserted into the very young pods. Most abundant in cultivated Mustard and cruciferous weeds and on clay soils. The stubble should be ploughed under deeply. (*b*) The Stem Weevil (*C. quadridens*), which feeds, as larva, in the stems. (*c*) The Seed-leaf Weevil (*C. contractus*), which feeds in the cotyledons of swede and turnip, causing brown patches before these leaves appear above ground. The plants die off quickly in drought or other adverse weather. The seeds yield from 5 to 7 tons more per acre if soaked in paraffin or turpentine for several hours before sowing.

**Turnip Mud Beetle** (*Helophorus rugosus*).—Widely distributed in England and Wales, rarer in Scotland, except the border counties and Aberdeenshire.

*Description.*—Larva up to $\frac{1}{4}$ in. in length, yellowish white with two rows large, square, dark spots down the back, and smaller ones, from which arise bristles, at the sides; three pairs of legs; last body-segment with two projections.

Beetles $\frac{1}{4}$ in. long, oval, broad, reddish brown with paler legs; wing-covers nearly three times as long as broad, ridged, with punctures in the furrows; capable of flight.

*Crops Attacked.*—Turnips.

*Symptoms.*—Roots stunted, hard and woody, gnawed and tunnelled. Leaves may curl up and may appear gnawed; leaf-stalks weak from mining. Larvæ and beetles found particularly in the crown amongst the leaf-bases.

*Life History.*—Little is known. Apparently the larvæ pupate in the soil.

*Control.*—Avoid sowing turnips near to a field which has been affected. During attack, stimulate growth of the crop by applying nitrate of soda, 1 cwt. per acre. After attack, plough deeply to smother the pupæ.

## 2. Fly Maggots.

**Cabbage and Turnip Root Maggot** (*Chortophila brassicæ*, *Phorbia brassicæ*, or *Pegomyia brassicæ*), fig. 20.—An underground pest, on light soils; most injurious to young plants.

*Description.*—Larva, a typical maggot (see p. 274) up to $\frac{1}{3}$ in. long, white or yellowish with twelve rounded tubercles at the hind end enclosing two brown spiracles. Pupa enclosed in a reddish brown puparium (see p. 274) $\frac{1}{4}$ in. long. Fly, $\frac{3}{16}$ in. long, smaller, narrower bodied, and longer winged than the common house-fly; bristly. Egg about $\frac{1}{25}$ in. long, white, spindle-shaped, with a ridge along one surface.

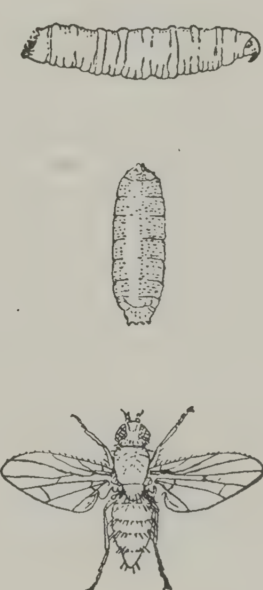


Fig. 20.—Root Maggot, Puparium, and Fly enlarged

*Crops Attacked.*—Cabbages, cauliflowers, broccoli. Brussels sprouts, radishes, turnips, swedes.

*Symptoms.*—Growth is checked, leaves droop and discolour, roots are destroyed, the rootlets being eaten away. Maggots are found around the main root or in the soil close by.

*Life History.*—Flies emerge in late April or early May and lay eggs, one or two to each plant, just below soil surface, usually in a crevice of the root. These hatch in three to seven days. Maggots feed for about three weeks and pupate in the soil or in the roots. Flies may emerge in two weeks in summer, lay eggs, and produce a second brood. Possibly a third brood may occur. The first brood is the most injurious, since the plants are young. The last brood winters in the pupa state, after feeding late into autumn on the stumps or roots.

*Wild Food Plants.*—Almost all Crucifers, such as Charlock, Shepherd's Purse, Hedge and Black Mustard, Winter Cress, Jack-by-the-Hedge, Wild Radish, &c.

*Control.*—Use clean seed; hoe or harrow spring shoots; cut the young weeds or spray them with iron sulphate (2 lb. to 1 gall. water) to prevent seeding. Shelter seed-beds from the flies by 12-in. board frames covered with cheese cloth, supported by wire. Avoid farmyard manure where attack is likely, as this attracts flies. Plant out as late as possible. Protect each root when planting out by a tarred felt disc, about 3 in. in diameter, with a long slit extending from one edge two-thirds of the way across and a short slit at right angles. Clip this round the stem at ground-level and press well down to exclude egg-laying flies. The Board of Agriculture gives the average cost of these discs at 8*s*. per 1000. They have proved most effective in America.

Where egg-laying is noticed or suspected, water the roots immediately with corrosive sublimate (1 oz. to every 8 gall. water), repeating twice or three times at intervals of five days. A gallon covers twenty plants on smooth, fairly moist soil; more is required to penetrate dry or lumpy ground. This is found to be very effective but only if applied early, when the plants are 2½ to 3 in. high.

### Other Fly Maggots attacking Turnips and Allied Plants.

**The Yellow Turnip-leaf Miner Fly** of Curtis (*Farm Insects*, p. 84) is allied to or possibly identical with *Scaptomyza flaveola*, Meigen, of which the larva has been described as mining the leaves of cabbage, cauliflower, radish, and turnip in the United States, and as feeding on the upper surface of the leaves of turnips in Ireland (Carpenter, *Journal of Economic Biology*, Vol. VI, No. 3, 1911, p. 71) and causing them to curl.

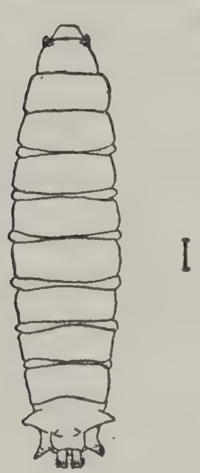


Fig. 21.—Scaptomyza Maggot (after Carpenter)

The maggot (fig. 21), about ⅛ in. long, white, is characterized by a bristly cuticle and a pair of prominent tubes at the hind end, carrying the last pair of spiracles. The front spiracles have a group of tubes arranged like fingers of a hand. The puparium has at its front end a pair of antlerlike projections branching into the tubular openings of the front spiracles. The adult fly is yellow and a little more than $\frac{1}{20}$ in. in length.

**The Black Turnip-leaf Miner** (*Phytomyza nigricornis*, Macquart), of which the fly is smaller than the above and slaty black with yellow head and brown antennæ or feelers. The larva burrows within the leaves, nearer to the under surface.

**The Curly-leaf Midge** (*Contarinia nasturtii*), of which the larva

has been described as injuring the leaves of rape (United States), cauliflowers (Denmark), and swedes (Ireland)—in the last case causing abnormal swellings of the leaf-stalks just above the roots—is one of the Gall Midges (Cecidomyidæ), minute flies with thread-like antennæ. Its footless larva (fig. 22), which feeds between the bases of the leaf-stalks in swedes, is creamy white, about $\frac{1}{8}$ in. long, and tapering towards both ends. It has a dark yellow Y-shaped, horny "anchor process" on the under side of the segment (prothorax) following the minute head. This insect pupates in the soil.

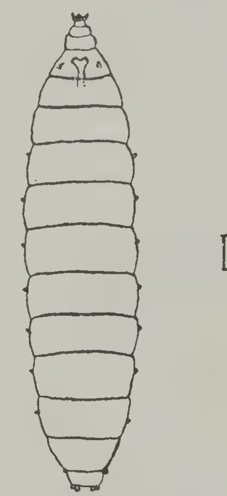


Fig. 22.—Contarinia Larva (after Carpenter)

All the above, together with various scavenging fly-larvæ, such as *Sciara* spp., *Phora rufipes*, and *Fannia canicularis*, are liable to accompany the attack of the Root Maggot (*Chortophila brassicæ*).

In Germany a Rape-pod Midge (*Perrisia brassicæ*) has been found causing damage after Seed Weevil attack.

### 3. Caterpillars.

These are the larvæ of several kinds of Butterflies and Moths, e.g. the Large Cabbage White Butterfly (*Pieris brassicæ*), the Small White (*P. rapæ*), the Green-veined White (*P. napi*), the Cabbage Moth (*Mamestra*, or *Barathra brassicæ*), and the Diamond-back Moth (*Plutella maculipennis*). See also "Surface Caterpillars", p. 278, and "Silver Y Moth", p. 300.

*Description.*—The caterpillar of *P. brassicæ* (fig. 23) is greenish yellow, covered with black spots, with a yellow line down the back and one on each side of the body, with a thin covering of short hairs. Length up to $1\frac{1}{4}$ in. That of *P. rapæ* is pale green, finely spotted with black and yellow, velvety, and does not exceed 1 in. in length. That of *P. napi* is green with reddish spiracles and has a narrow yellow line down the back.

That of *M.* (*B.*) *brassicæ* (fig. 24) is light green at first, with scattered hairs and with relatively larger head than the previous ones. As growth proceeds it becomes smooth and usually dark coloured above, brown, with lighter under surface; length, $1\frac{1}{4}$ in. That of *Plutella maculipennis* (fig. 25) is smaller, almost smooth, markedly spindle-shaped, flattened from above, and very active when disturbed. At first it is grey with dark head, later pale green with greyish head. Length rarely exceeds $\frac{1}{2}$ in.

*Crops Attacked.*—Cabbages, kales, cauliflowers, turnip, swedes, rape, mustard, lettuce (Cabbage Moth), beet (Diamond-back Moth).

*Symptoms.*—The leaves are perforated and the plant becomes sickly and yellow. The droppings of the caterpillars, and the insects themselves, can be seen.

The Butterfly caterpillars skeletonize the leaves. The Diamond-back

Moth caterpillar eats more particularly the lower and central tissues of the leaf, leaving the upper skin intact and window-like. The Cabbage Moth caterpillar at first eats the outer leaves and later bores into the heart of the plant, which becomes soiled with its droppings. At this stage it is invisible from the outside. The others can all be found at the surface.

**Life Histories.**

1. *Large Cabbage White.*—Butterflies emerge in spring, lay conical yellow eggs in batches of twenty to one hundred on the leaves of various cruciferous weeds. Hatch in a fortnight. The young caterpillars feed together in clusters at first, but more widely later. Full fed in about a month, they leave the plant and climb trees, fences, walls, &c., even reaching the eaves or under side of the roofs of sheds, where they attach themselves by a pad of silk at the hind end and a thread round the middle and change to pupæ, yellowish white with black spots and irregular in outline, with angular projections. In about three weeks, say in July or August, the late summer Butterflies emerge, eggs are laid on cabbages, &c., and a second brood of caterpillars, the more destructive one, is produced. These feed until the end of September or later, passing the winter as chrysalides.

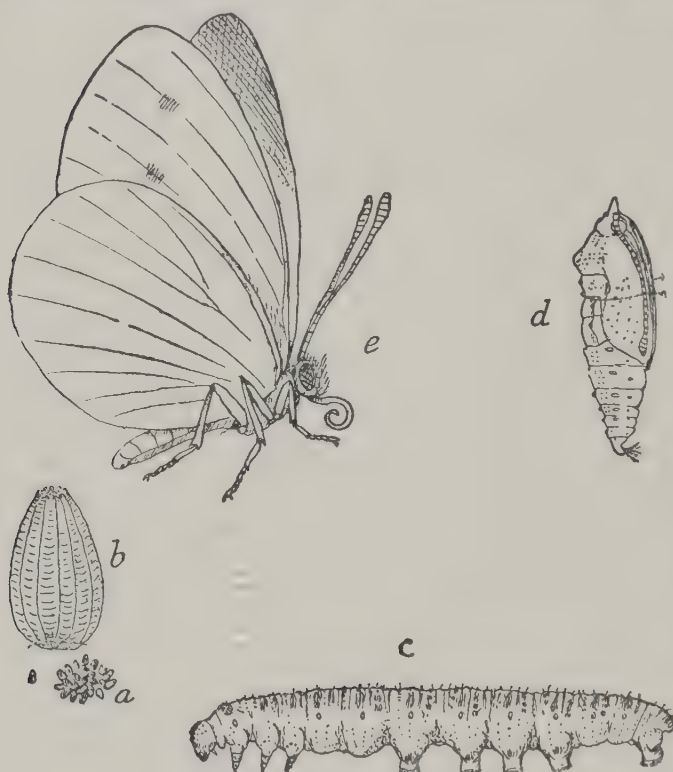


Fig. 23.—Cabbage Butterfly

(*a*) Eggs, natural size; (*b*) egg enlarged; (*c*) caterpillar; (*d*) chrysalis; (*e*) butterfly.

2. *The Small White and Green-veined White* agree in general with the above, but the eggs are laid singly on the leaves of the food plant and the caterpillars are solitary in habits.

3. *The Cabbage Moth* (fig. 24) emerges in early summer, flies only by night, and lays bun-shaped eggs, probably most often in batches, on the leaves or leaf-stalks of the food plants. The larva feeds for four or five weeks and then drops to the ground, forms an earthen cell, and becomes a chestnut-brown pupa, smooth in outline. In this state the winter is passed, though a late summer generation of moths may emerge and produce a second brood of caterpillars before the wintering.

4. *Diamond-back Moth* (fig. 25) emerges in spring from the pupa. Eggs are laid singly or in groups (two to five) on lower surface of leaves of turnips, cabbages, beetroot, &c., and of cruciferous weeds. Hatch in about six days. The larva at first mines the leaves, moults once, and then feeds on the surface, from fourteen to twenty-eight days; spins a silk bag or cocoon around itself on the leaf, and pupates within it; ten to fifteen days to emergence.

Two or three broods of larvæ, according to district and climate. Winter is passed in pupa state on stalks and dead leaves of weeds and on rubbish.

The moths do not travel far unless carried by the wind.

*Wild Food Plants.*—All the above caterpillars feed upon Crucifers of all kinds, especially Charlock, Hedge Mustard, Horse-radish, and Shepherd's Purse, whilst the Diamond-back is found also on Saltwort (Chenopodiaceæ) and other plants.

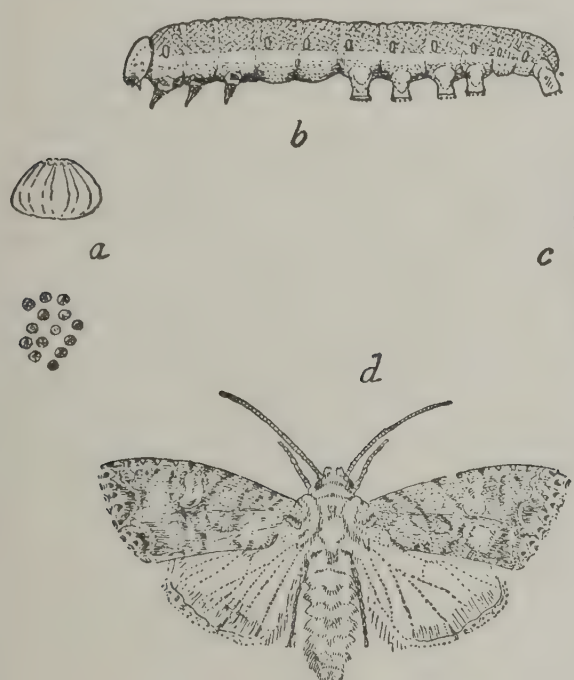



Fig. 24.—Cabbage Moth

(*a*) Eggs, natural size and enlarged; (*b*) caterpillar; (*c*) pupa; (*d*) moth.

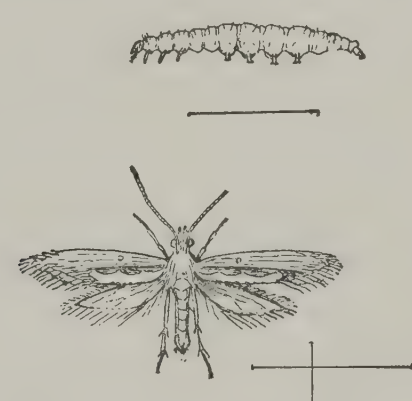


Fig. 25.—Diamond-back Moth and Caterpillar

*Control.*—Clean cultivation and quick rotation. Watchfulness for signs of attack or of the presence of the butterflies or moths on the wing. Even on a large scale it will be worth while to examine the plants weekly for eggs or caterpillars and to crush the former in the case of Large White, to collect and destroy the latter in all cases, except when showing signs of disease which is due to natural enemies of the insects. The small silk cocoons found near dead or dying caterpillars should be preserved as they contain valuable parasites. All pupæ found should be destroyed. Thorough dusting of the plants, both above and below the leaves, with soot 3 parts, ground lime 1 part, distributed at the rate of 2 to 6 bus. an acre by a dusting machine, used when the plants are damp with rain or dew,

has been found effective, during attack, for both the Whites and Diamond-back; also spraying both sides of the leaves with soap (1 lb to every 8 gall. water). Birds, such as rooks, starlings, plovers, and gulls, should be allowed free access to plants attacked. Caterpillars may be dislodged by branches attached to the sides of a horse-hoe, followed by another to crush them.

### 4. False Caterpillars.

Attack turnips; known as Black Slug, Black Palmer, Black Canker, or Nigger. These are the larvæ of the Turnip Sawfly (*Athalia spinarum*), fig. 26, which is a shining orange-coloured insect with four membranous wings, yellow at the base, with a wing-stretch of $\frac{3}{5}$ in. The thorax is black above, in both sexes, and head black. The fly feeds on the pollen of Cruciferæ and Umbelliferæ, but is not injurious in this stage.

*Description.*—The larva, white at first, greenish later, and finally almost black with a lighter stripe along the sides, reaches a length of $\frac{3}{4}$ in. It has a dark head and a caterpillar-like body, warty but hairless. The first three segments are inflated, and carry each a pair of jointed legs, the next is limbless, the fifth to the twelfth have paired fleshy claspers or prolegs with a rounded extremity. It lies curled up on the leaf or feeds at the edge or upon the surface. It is most destructive in the southern counties of England.

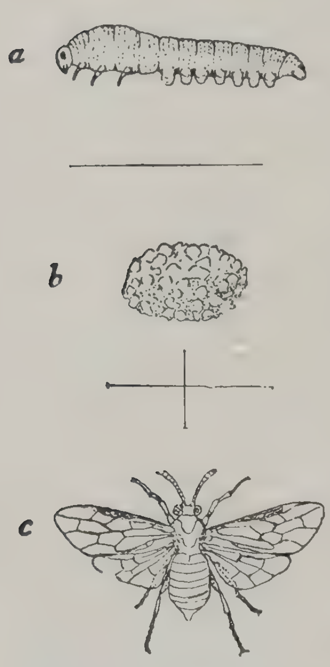


Fig. 26.—Turnip Sawfly
(*a*) Larva; (*b*) cocoon; (*c*) fly.

*Crops Attacked.*—Principally turnips, less frequently swedes.

*Symptoms.*—The leaves are perforated and skeletonized. The larvæ are found on their surface, particularly at the edges.

*Life History.*—The Sawflies appear in May and lay two hundred to three hundred oval eggs singly in cuts made with their tail-saws, near the margin of the outer rough leaves or the leaflets near the base. These hatch in about a week. The larva feeds for about three weeks, drops to the ground, and pupates just below the surface in a brown sticky cocoon which becomes coated with earth particles. The adults may emerge in three weeks, but late in the season the larvæ may remain for three months encased before changing to pupæ. The eggs of the late summer-emerging flies give rise to larvæ which feed through September and October, doing much damage. They winter underground as larvæ in the cocoons, changing to pupæ in the spring.

*Wild Food Plants.*—Not recorded; probably cruciferous weeds. The adults are found on the flowers of Cruciferæ and Umbelliferæ.

*Control.*—The insects appear so unexpectedly in large numbers that no general precautions beyond rotation and clean cultivation seem to be called for.

During an attack the leaves may be dusted with soot and lime (see under "3. Caterpillars"). If only a part of the field shows attack it should be isolated by a furrow, deepened to a trench steep on the far side, containing water, or straw which can be collected and burnt. Hand picking or sweeping with a rope or with branches attached to the front of the drill-grubber, which crushes the larvæ dislodged, has been found effective. Spraying with strong paraffin emulsion is useful. Dissolve 28 lb. soft soap in 28 gall. of boiling water. Stir in, whilst boiling, but not over the fire, $12\frac{1}{2}$ pt. of paraffin. Make up to 100 gall. with soft water. This is sufficient for 2 ac. (Somerville, 1903). Ducks or fowls will clear an affected field. Rooks feed on the larvæ and should not be disturbed in attack. After attack infested fields should be deeply ploughed with a skim-coulter to bury the cocoons and prevent emergence.

5. **Bugs** (Rhynchota).

**Cabbage Aphis or Greenfly** (*Aphis* (*Brevicoryne*) *brassicæ*) is abundant principally in dry hot weather.

*Description.*—The wingless viviparous females (fig. 27) are about $\frac{1}{10}$ in. long, grey-green with dark spots on the upper surface; antennæ green or yellowish with dark tips; legs and eyes brown to black; cornicles or tubes on the back short, dark brown; all covered by a mealy secretion which gives a pearly white appearance. The young are yellowish. The winged viviparous females are black in front, yellow-green behind, covered with mealy secretion; wings iridescent with pale green spot. The males are green with black antennæ; cornicles dark at base. The oviparous females are green with rows of dark spots on back; have a sabre-shaped ovipositor behind.

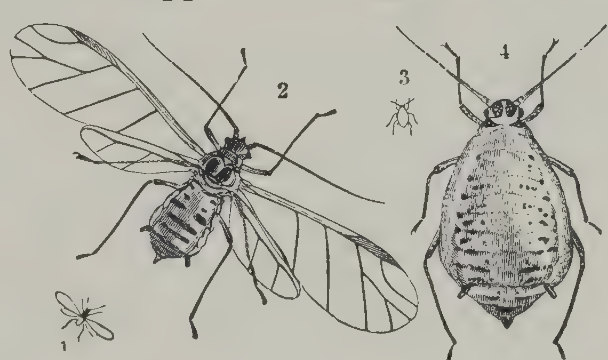


Fig. 27.—Cabbage Aphis
1 and 2, winged, 3 and 4, wingless, viviparous females natural size and enlarged.

*Crops Attacked.*—Principally cabbages, also swedes and broccoli.

*Symptoms.*—The leaves become yellow and bleached; blisters appear and sooty coloured patches may develop. The Aphides are visible in groups.

*Nature of Attack.*—All stages suck the sap and weaken the plants. The stomata of the leaf are clogged with a sticky substance, "honeydew",

from the intestine of the insects, which also favours fungus attack, as a germinating medium for the spores.

*Life History.*—Eggs are laid in autumn on various cruciferous plants. In this stage the winter is passed.

From the eggs emerge wingless and winged virgin females which produce active young. These feed and reproduce in the same manner. The winged females spread from plant to plant. Late in the season, when the infestation is at its worst, males and wingless females are produced, which pair, giving rise to the winter eggs.

*Wild Food Plants.*—Cruciferous weeds of all kinds.

*Control.*—Destroy cruciferous weeds and refuse of crops. Water the insects with soap and water (1 part soft soap, 8 parts boiling water, 1 part of paraffin, mixed and diluted with 16 times its bulk of water; or 3 parts white soft soap, 5 to 6 parts methylated spirits in 91 to 92 parts water, or $1\frac{1}{2}$ of each if better quality of soap is used) as soon as they are seen, repeating if necessary. In the United States dusting with nicotine sulphate (2 per cent or more mixed with kaolin and lime) has been found cheap and effective. In Algiers a dust of 100 parts powdered lime to 30 parts tobacco powder has been successful.

**Turnip Aphides** include Turnip-leaf Plant Louse (*Aphis rapæ*, Curtis), Turnip-flower Plant Louse (*A. floris rapæ*, Curtis), and other species. They are very similar in appearance, habits, and life history to the Cabbage Aphis, and require similar treatment. All these Aphides have a number of insect enemies, such as Ladybird Beetles, predaceous Bugs of various species, the larvæ of Hover Flies and Lacewing Flies, also the parasitic black, wasp-like insects of microscopic size (Braconids) which lay their eggs in the bodies of the Aphides, causing them to swell and turn brown. Every possible protection should be given to these insects found to frequent the colonies of Aphides. Even spraying should be avoided in such cases.

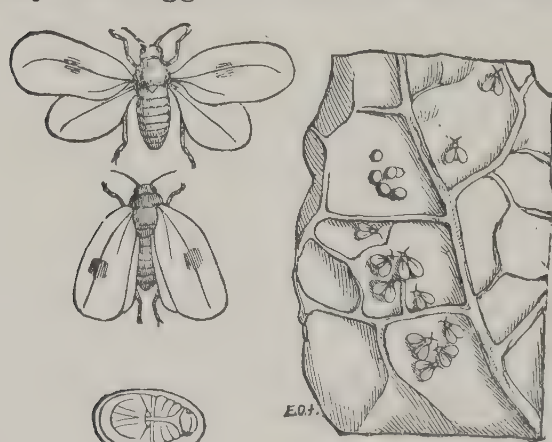


Fig. 28.—Cabbage Snowfly
Flies and nymph (below), enlarged, also natural size, on leaf.

**Cabbage Snowfly** (*Aleyrodes proletella*, Linn., probably = *A. brassicæ*, Wlk., fig. 28) was abundant in the south of England in the autumn of 1921.

*Description.*—The adult has evenly rounded white wings, $\frac{1}{10}$ in. from tip to tip when expanded, with a single vein on each, and resembles a small snowy Moth. The larva is powdered with white, yellowish, flattened and scale-like with a fringe of thread-like projections. The nymph, hidden under the scale, has red eyes.

*Crops Attacked.*—Cabbage.

*Symptoms.*—Wilting and blotching of the under surface of leaves, where the larvæ have pierced with their beaks and injected " saliva ". The adults rise in a snowy cloud when disturbed.

*Life History.*—Eggs, laid in a group on a leaf, hatch in about twelve days. The larva feeds for about ten days like a scale insect. Under the larval covering transformation takes place in about four days.

*Wild Food Plants.*—Various, including Crucifers and the Greater Celandine (Papaveraceæ).

*Control.*—During attack, hand-picking and burning infested leaves has been found most effective. Dusting with tobacco powder or with flowers of sulphur has been recommended.

## 6. Other Injurious Insects.

Thrips (see Vol. I, p. 351), species of which attack the flower-heads.

Springtails (Collembola), especially a white species (*Lipura ambulans*, fig. 10, p. 280), less than $\frac{1}{16}$ in. long, without a spring; and a greenish grey species (*Hypogastrura* (*Achorutes*) *armata*), fig. 29 *a*, of similar size, but having a short spring on the fourth abdominal segment below. Both species gnaw the young roots, especially if already softened and decomposed by other injury. A globular-bodied, yellow species (*Smynthurus luteus*, fig. 29 *b*) is said to injure the leaves of seedling turnips and cabbages.

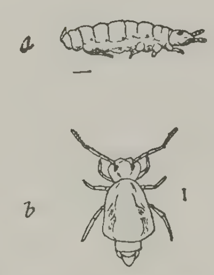



Fig. 29.—Springtails

(*a*) *Achorutes armata*; (*b*) *Smynthurus luteus* (both after Lubbock)

*Control.*—See section A, p. 280.

## C. Beet, Sugar Beet, Mangold Wurzel (Family Chenopodiaceæ).

The roots are liable to attack by:

*Beetles and their Grubs*: Ground Beetles (*Steropus madidus*), Wireworms (see Vol. I, p. 337), White Grubs (see Vol. I, p. 339).
*Fly Maggots*: Mangold Fly.
*Caterpillars*: Surface Caterpillars or Cutworms.
*Springtails*: Smynthurus.
*Millepedes*: Blanjulus and Julus.
*Eelworms*: Beet Eelworm.

The leaves are liable to attack by:

*Beetles and their Grubs*: Beet Carrion Beetle, Pigmy Mangold Beetle, Flea Beetle.
*Caterpillars*: Silver Y Moth, Diamond-back Moth.
*Bugs*: Bean Aphis.

## 1 Beetles.

**Beet Carrion Beetle** (*Blitophaga opaca*), fig. 30.

*Description.*—Larva about ½ in. long, shining black, somewhat flattened, resembling a Woodlouse, but with only six legs and with two tail processes behind. Beetle about ⅖ in. long, oblong oval, flat, black with a covering of short yellowish hairs; wing-covers with three longitudinal ridges on each; antennæ clubbed.

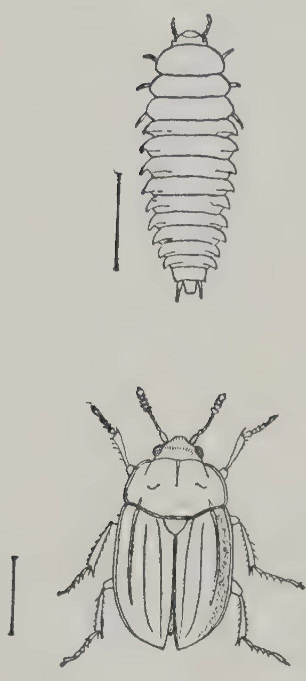


Fig. 30.—Carrion Beetle and Larva

*Crops Attacked.*—Beet, mangold wurzel.

*Symptoms.*—The leaves are eaten away to the ribs. The larvæ may be found on the leaves at night. The adults destroy the leaves in spring, attacked leaves showing black edges.

*Life History.*—Eggs are laid in spring in soil about the roots and also in manure and decaying animal or vegetable refuse. Hatch in about a fortnight. Feed for a month, mostly at night on decaying matter and also on the leaves. Pupate in the soil about the beginning of July. Beetle emerges in about three weeks. The winter is passed in the beetle state.

*Wild Food Plants.*—The insect, being mainly a carrion feeder or a scavenger, does not appear to be recorded from wild plants.

*Control.*—(*a*) Prevention. Avoidance of animal refuse in manuring (*b*) Remedy. Spraying at night with paraffin emulsion (soft soap ½ lb., boiling water 1 gall., paraffin 2 gall., well mixed, diluted with 24 to 49 times its volume of water) or with barium chloride, a 4 per cent solution.

Avoid thinning as this would increase infestation on the remaining plants.

Fig. 31.—Flea Beetle (*P. concinna*)

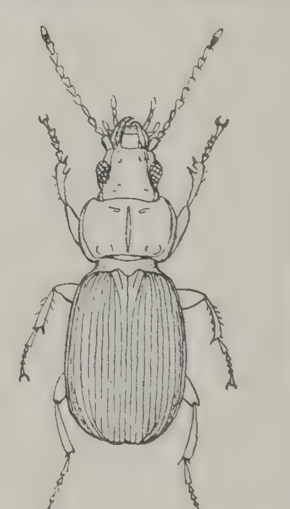


Fig. 32.—Ground Beetle (*S. madidus*)

### Other Beetles attacking Beet and Mangold.

**Flea Beetles** (see section B, p. 285), especially *Plectroscelis concinna* (fig. 31), brassy black in colour.

**Ground Beetles,** usually regarded as carnivorous in habit, especially *Steropus madidus* (fig. 32), which gnaws the roots of mangolds, feeding at night.

**The Pigmy Mangold Beetle** (*Atomaria linearis*), fig. 33, a narrow-bodied beetle, black to reddish brown in colour, about $\frac{1}{24}$ to $\frac{1}{18}$ in. in length, eating the seed leaves, the rough leaf, and the root of mangolds and beet. The root of seedlings may show constriction below ground-level. Heavy rolling to consolidate the seed-bed and hoeing in a heavy dressing of soot round the young plants have been found beneficial.

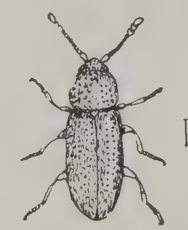


Fig. 33.—Pigmy Beetle

**Wireworms and White Grubs.**—Attack the roots (see Vol. I, pp. 337, 339).

## 2. Fly Maggots.

**Mangold Fly** (*Pegomyia betæ*).

*Description.*—Larva, a typical maggot, $\frac{1}{3}$ to $\frac{2}{5}$ in. long when full fed, greenish white. Puparium oval, brown, about $\frac{1}{5}$ in. long. Fly about $\frac{1}{5}$ in. long with a wing-spread of $\frac{12}{25}$ in., ashy grey to dark grey with black bristles and three or five indistinct longitudinal stripes on fore-body; abdomen paler with a dark middle line on the last four segments; legs yellow in the female, darker, with some yellow, in the male. Eggs oval, white, sculptured, $\frac{1}{25}$ in. long.

*Crops Attacked.*—Mangolds, sugar beet, spinach.

*Symptoms.*—Young singled plants beginning to grow, droop and wither. Pale blotches or blisters appear especially on the outer leaves.

*Life History.*—Flies appear in June and lay eggs in small groups on under surface of leaves. Hatch in five days or more. Larvæ mine the leaves irregularly for ten to twenty-one days. Occasionally form their puparia in the blisters, more usually in the soil. Flies may emerge in fourteen to twenty days. There are at least three broods in a year. The last larvæ winter in puparia.

*Wild Food Plants.*—Henbane, Belladonna, Goosefoot.

*Control.*—Farmyard manure, if used, should be ploughed in early to avoid attracting the flies. Seed should be sown thickly and growth stimulated by potash or superphosphate. The flies may be caught on sacks, covered with adhesive substance, suspended from a horse-raking machine in place of the rake. A machine 6 ft. wide can cover 18 ac. in a day.

During attack, hand-crushing the discoloured patches on the leaves or hand-picking the leaves is most effective, as the mining larva is protected from insecticides. After attack, winter cultivation exposes the puparia to birds. The crop should be changed.

## 3. Caterpillars.

**The Silver Y Moth** (*Plusia gamma*), fig. 34.

*Description.*—Larva, $1\frac{1}{4}$ in. long, green with six longitudinal white lines and a yellow line on each side above the legs; only three pairs of

claspers on the hind-body. Pupa brown, enclosed in a thin web of silk.

Moth, wing-stretch about $1\frac{1}{2}$ in.; colour of fore-wings brownish grey with wavy, reddish brown lines and markings, a silvery Y on each wing; hind-wings pale brown, fringed with lighter hairs.

Fig. 34.—Silver Y Moth and Caterpillar

*Crops Attacked.*—Beetroot, cabbage, peas, vetches, clover.

*Symptoms.*—The leaves are eaten and the caterpillar is found upon them.

*Life History.*—Eggs laid in summer on under side of leaves of crops or weeds. Hatch in about fourteen days. Caterpillars feed for a month and pupate in a web on under side of leaves of food plant. Moth emerges in a fortnight. There are two or more generations in a year; some winter as half-grown caterpillars, some as moths.

*Wild Food Plants.*—Nettle, Sowthistle, Wild Geranium, Dead Nettle, &c.

*Control.*—Clear out weeds. Hand-pick the caterpillars or drag ropes across the plants and turn poultry among them to pick up the caterpillars dislodged.

**Other Moth Caterpillars recorded as Injurious to these Root Crops.**

**Surface Caterpillars** (see section A, p. 278), especially the Turnip Moth (*Euxoa segetum*); also

**Diamond-back Moth** (*Plutella maculipennis*) (see p. 291).

4. **Bugs** (Rhynchota).

Beet and mangolds are attacked by a number of species of Plant Lice (Aphides), Leaf Hoppers, and other Bugs. In America these insects have been found capable of conveying mosaic disease of sugar beet. In Britain, occasionally during drought, these plants are invaded by vast hordes of the Bean Aphis (*Aphis rumicis*).

*Description.*—All forms and stages more or less black, shiny, or velvety owing to waxy covering, with antennæ pale in the middle and legs pale on the base of the thigh (femur) and on the lower leg (tibia). Adults about $\frac{1}{12}$ in. long both in winged and wingless forms.

*Crops Attacked.*—Mangold, beet, broad beans, French beans, peas, onions, leeks.

*Symptoms.*—In mangold and beet the leaves curl towards the lower surface on which the insects feed by their sucking beak.

*Life History.*—Winter as eggs, in some cases on the spindle tree (*Euonymus*), in others on the Dock (*Rumex*). Wingless females appear in spring and reproduce without mating, since no males are present, and without laying eggs, the young being born active and ready to feed. These grow and reproduce in the same way, some of their offspring, all females, becoming winged in the course of growth. The winged females migrate to other plants, e.g. from spindle tree to poppies, from poppies to mangolds, &c., or from docks to beans, &c. (F. V. Theobald, *Journal of the Board of Agriculture*, 1912).

In autumn wingless egg-laying females and winged males are produced after migration to Euonymus or Dock. Fertilized eggs are laid on these plants for the winter.

*Wild Food Plants.*—Poppy, Dock, Thistle, Gorse, Foxglove, Pimpernel.

*Control.*—The power of flight of these insects makes prevention impracticable. If dry weather is continuous paraffin emulsion or a nicotine spray (nicotine 5 oz., soft soap 2 to 12 lb., according to hardness of water, water 100 gall.) should be kept ready for early stages of attack. Plants attacked may be dusted with soot or powdered quicklime.

### 5. Other Insects.

**Springtails** (Collembola).—A yellow, globular species (*Smynthurus hortensis*) has recently been found injuring yellow mangolds at ground-level, causing bleeding of roots and constriction of the seedlings just below the crown. As the insect never feeds below ground, earthing up, to cover the roots, should be effective.

### 6. Animal Organisms other than Insects.

**Millepedes,** especially *Blanjulus pulchellus* and *Julus terrestris*, a larger species of uniform grey colour. Both these are liable to be brought to the fields in stable manure (see under "Potatoes", p. 281).

*Control.*—Rolling the fields tends to hinder the access of the Millepedes to young plants and germinating seeds. Seed may be protected by treatment for twenty minutes in a solution of 5 parts magnesium sulphate and 1 part carbolic acid in 100 parts of water, before sowing on infested ground.

**Eelworms** (Nematodes).

**Beet Eelworm** (*Heterodera Schachtii*), fig. 35.

*Description.*—In the larval state is microscopic, about $\frac{1}{75}$ in. in length, tapering towards both ends, eel-like and transparent. The mature female is about the size of a pin's head, yellow, and lemon-shaped. The mature male resembles the larva in general form.

*Crops Attacked.*—Beet, mangold, Crucifers and leguminous plants.

*Symptoms.*—Infected plants grow less rapidly than sound ones and

become celery-like in appearance. Growth may cease and the root fail to enlarge, though this is not always the case. The lateral roots are found to be studded with knots like pearls. These are the pregnant females.

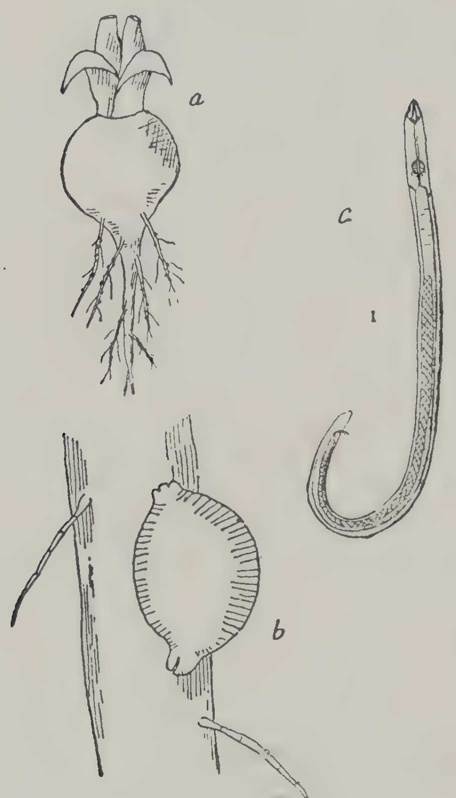


Fig. 35.—Beet Eelworm

(*a*) Root showing rootlets attacked; (*b*) female worm on rootlet, enlarged; (*c*) male worm, much enlarged.

*Life History.*—The larvæ present in infected soil enter the young plants in spring and attach themselves to the roots. They moult, or cast their outer covering, on attaining maturity. The male impregnates the female, which then increases in size and projects from the root. These gravid females are found from the beginning of June, and by the autumn their bodies have become lemon-shaped yellow brood-capsules containing some hundreds of eggs. From these eggs young larvæ escape into the soil. They are always present when the crop is grown for many years successively in the same field.

*Wild Food Plants.*—Cruciferous and other weeds serve as alternative hosts for the maturing of the Eelworms.

*Control.*—Removal of weeds; rotation of crops—the eggs can survive drying up for several years—uprooting and burning diseased plants; treating the soil around diseased plants with sulphate of potash (4 cwt. to the acre), which prevents the migration from one plant to another. It should be applied on suspected land shortly before the seed is sown. Watering the soil with formaldehyde (0·25 per cent) has been found effective as a sterilizer. Trap plants (summer rape) can be sown, several crops in succession. These plants may be killed by spraying with a 30-per-cent solution of sulphate of iron. The Nematodes continue in the roots but no eggs are produced.

## D. Carrots and Parsnips (Family Umbelliferæ).

The roots are attacked by

*Fly Maggots*: Leather Jackets, Rust Maggot, Lesser Bulb Fly.
*Caterpillars*: Surface Caterpillars, Swift Moths.
*Bugs*: Carrot Aphis.

The leaves, &c., are attacked by:

*Fly Maggots*: Celery or Parsnip Fly.
*Caterpillars*: Flat-body Moths (*Depressaria* spp.).
*Bugs*: Carrot Aphis.

### 1. Fly Maggots.

**The Carrot Rust Maggot** (*Psila rosæ*), fig. 36.

*Description.*—Larva, a slender shiny maggot, yellowish, up to $\frac{1}{3}$ in. long, smooth except for a group of spines on the under surface of each segment.

Puparium, horny, shining, light brown, $\frac{1}{4}$ in. long, elongated, obliquely blunted in front.

Fly, narrow bodied, $\frac{1}{6}$ in. long, shining black or greenish black with head rusty red, eyes black, antennæ with third joint half black, half yellow; legs yellow; two pairs bristles in centre of back of thorax. Wings pearly with dark yellow veins. Wing-spread $\frac{1}{3}$ in. Female with a pointed egg-tube at hind end.

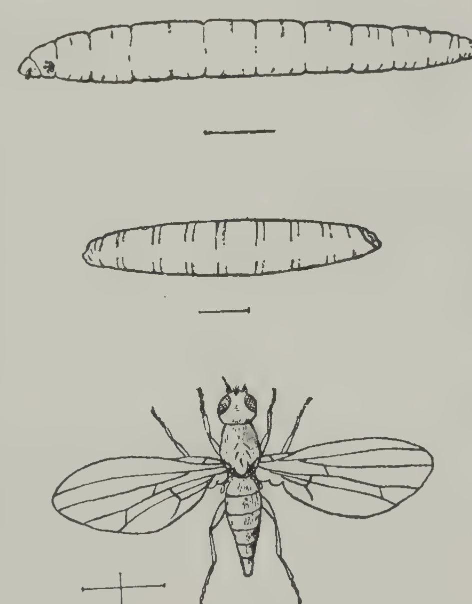


Fig. 36.—Rust Maggot, Puparium, and Fly

Egg, $\frac{1}{50}$ in. long, spindle-shaped, longitudinally ridged, and with a rounded "cap" at one end.

*Crops Attacked.*—Carrots, parsnips, celery, parsley, turnips, &c.

*Symptoms.*—Leaves turn "rusty", or pale and withered. Growth is checked. Roots become brown and rot, and may show deep cracks containing the maggots, which may project from the surface. Millepedes, Woodlice, and Slugs may attack the decaying roots.

*Life History.*—Winter mainly as pupæ. Two generations occur in the year. The first flies appear in May or early June, lay eggs close to the roots, just below soil surface. Larvæ hatch from mid-June to mid-July, going down to the tender root and working upwards, throwing out a yellowish dust (rust) at the surface of the carrot. Full fed from mid-July to early August, they leave the plant and become puparia at a depth of 3 to 4 in. in the soil. A second flight of adults may emerge in a month (i.e. from early August) or later (up to late October), but many pupæ of the first generation remain as such over the winter. Eggs of the second flight produce larvæ which pupate, for the winter, usually about the end of September; but some of these larvæ may continue to feed in carrots stored in warm places. Possibly some adults also hibernate.

*Wild Food Plants.*—Not known with certainty, but probably Umbelliferæ, such as Cow Parsley (Anthriscus), &c.

*Control.*—Prevention of attack depends upon:

(*a*) Rotation, to avoid frequent planting of carrot or other root-crops on the same land.

(*b*) Careful preparation of the ground to secure rapid growth.

(*c*) *Timing* of the crops to avoid the egg-laying seasons of the fly for the weak stages of the plants.

(*d*) As *little disturbance* as possible of *the soil* around the growing plants to lessen attraction of flies and to hinder their access to the roots.

(*e*) Use of *deterrents* to mask the " carrot smell " or to render the soil distasteful for egg-laying.

(*f*) *Watchfulness* for first signs of attack and removal and destruction of affected plants with subsequent treading down of the soil or watering to consolidate it around remaining roots.

(*g*) After removal of an affected crop, heavy dressing with gas-lime (4 to 5 tons per acre) or deep ploughing to smother the pupæ.

Varieties of carrots suitable to the locality may be sown as late as May to avoid the first egg-laying (H. M. Smith, 1922), or, as recommended by the Board of Agriculture (Leaflet 38), early varieties, such as French Forcing, may be sown in February or March for early use, and the sowing of the main crop deferred until mid-July, when Early Horn variety may be used for winter storage. Very thin seeding may dispense with artificial thinning. Thinning, if necessary, should be done early and followed by consolidation (see (*f*) above).

Fig. 37.—Parsnip Maggot, Puparium, and Fly

*Deterrents* include sprays of paraffin emulsion after germination and again after thinning; also mixtures of green tar oil (1 part) and sand (99 parts), or paraffin and chalk scattered evenly between the rows; or finely crushed washing soda (1 part) and fine soil (10 parts), or derris powder (1 part) and soot (2 parts), dusted over the plants.

**The Parsnip Maggot** (*Acidia heraclei*), fig. 37.

*Description.*—Larva, a typical maggot, less than $\frac{1}{3}$ in. long, transparent greenish white with two button-like prominences behind.

Puparium, oval, slightly flattened, wrinkled, light yellow, $\frac{1}{8}$ to $\frac{1}{5}$ in. long.

Fly, nearly $\frac{1}{5}$ in. long, light brown to dark brown; wing-spread $\frac{1}{2}$ in.; wings pearly with brown bands and transparent spots; eyes green; legs yellow.

Egg, white, smooth, $\frac{1}{50}$ in. long, tapering towards the " capped " end.

*Crops Attacked.*—Parsnips, celery, parsley.

*Symptoms.*—Leaves blotched with yellow, then brown, where the

larvæ mine. They wither and the plants fail. Roots become misshapen.

*Life History.*—Winter as pupæ. Two generations in the year. First flies appear April or May and lay eggs singly or in small groups just within the skin of the under surface of the leaf. Larvæ hatch in from six to sixteen days and mine the leaves irregularly. Full fed in fourteen days or more, they drop to ground and become puparia about 2 in. below the surface. The second-flight adults emerge in about twenty-one days in summer, mainly in August. The larvæ from their eggs feed until November or later, and pupate for the winter 3 or 4 in. down in the soil (J. C. M. Gardner, 1922).

*Wild Food Plants.*—Umbelliferæ, such as Cow Parsnip (Heracleum), Angelica, &c., and Compositæ, such as Cotton Thistle (Onopordon), Corn Thistle (Cnicus), &c.

*Control.* (*a*) *Prevention.*—Rotation of crops and removal of weeds and crop-refuse; protection of seed-beds in sunshine by muslin screens; use of deterrents such as sprays of quassia extract, paraffin emulsion, green tar oil and soap (green tar oil 1 oz., soft soap 1 lb. to every 10 gall. of water), or dusts of soot and lime (3 parts soot, 1 part lime) when the flies appear.

(*b*) *During attack.*—Hand-crush the patches of the leaves and remove and burn badly affected plants. Encourage leaf-growth by nitrate of soda, a little salt, and frequent watering.

(*c*) *After attack.*—Remove and burn all crop-refuse, but replant a number of roots to act as traps for the next year. When heavily infested these may be collected and burnt (Gardner, 1922). Winter ploughing exposes puparia to birds and weather. Quicklime destroys them in the soil.

Other fly larvæ attacking these plants include Leather Jackets (see Vol. I, p. 343) and the Lesser Bulb Fly (*Eumerus Strigatus*). The latter is a maggot of $\frac{1}{4}$ to $\frac{1}{3}$ in. which has been found attacking also Narcissus, Hyacinth, and Onion.

Fig. 38.—Flat-body Moth

1 and 2, Moth enlarged. 4, Larva. 5, Pupa. (After Curtis).

## 2. Caterpillars.

**Surface Caterpillars** (see under "Potatoes", p. 278), especially Turnip Moth (*Euxoa segetum*) and Heart and Dart (*Agrotis exclamationis*), attack the roots, as do also those of the Swift Moths, Garden Swift (*Hepialus lupulinus*) (see p. 279) and Ghost Swift (*Hepialus humuli*), a larger species having larva up to $1\frac{1}{2}$ in.; adult with a wing-spread up to $2\frac{3}{4}$ in.; male almost white; female yellow in the fore-wings.

This latter species attacks carrots, Jerusalem artichoke, hops, potatoes, oats, and asparagus. Its wild food plants include Dandelion, Dead Nettle, Nettles, and Dock.

The caterpillars of several small flat-bodied Moths (*Depressaria* spp.), fig. 38, allied and very similar in appearance to the common clothes moths, at times attack the leaves, stalks, and flowers of carrot and parsnip. The larvæ are from $\frac{1}{3}$ to $\frac{1}{2}$ in. in length. They bind together the leaves or the flower-heads by silk threads, from which their presence may be recognized. They can be shaken out over a bucket or a tray. Dusting the flower-heads with soot and lime when wet with dew has been recommended.

### 3. **Bugs** (Rhynchota).

**Carrot Aphis** (*Aphis carotæ*), a subterranean species, appears to be one cause of the cracking of taproots. The Aphides are found in the cracks and also on the leaves (Theobald, 1909).

Powdered naphthalene worked into the soil about the roots of the plants and followed by watering would probably be effective over small areas.

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